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Modular Façade

that generates HEAT
using Biomass

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ABSTRACT

As the world's first renewable energy source, biomass has a lot of advantages which are being used nowadays for traditional or industrial purposes. The research conducted in this paper elaborates on the use of biomass energy in the commercial sector. The objective of the study is to propose a unitized façade system that integrates domestic biomass boilers for the generation of thermal energy used in heating and domestic hot water. A specific analysis on Barcelona and Ottawa proves the ability of the modular system to adapt to different climates by using different module combinations.

TECHNICAL STUDY

PART I - TECHNICAL STUDY
I.I. INTRODUCTION

Until recently, the world's primary energy relied mostly on non-renewable resources such as coal, oil and natural gas. These fossil fuels are environmentally damaging and are becoming too expensive to extract which is the main reason for human's search for alternative energy sources.

As a result, interest is shifting to renewable energy sources such as biomass, solar, wind and geothermal, resources which are inexhaustible and in constant renewal. In fact, many countries have taken the challenge to reduce their greenhouse gas emissions for the future.

Today, biomass is the world's 4th largest energy source after coal (*Figure 1*), oil (*Figure 2*) and natural gas (*Figure 3*) and it represents the 1st renewable energy source in the world.

Biomass energy (bioenergy) is energy from organic matter. It contributes to 14% of the world's primary energy consumption and researchers see a great future in it because of its cost-effective, sustainable supply of energy, and ability to help countries meet their greenhouse gas reduction targets.

Even though carbon is released when burning biomass, it is still classified as a renewable energy source considering the fact that plants absorb a large amount of carbon during their life cycle through photosynthesis; where they store the sun's energy.


Figure 1


Figure 2


Figure 3

I.I.

Biomass describes any organic matter available on a renewable basis.

There are different types of biomass: Natural, which comes from tree cuts and forest cleaning (Figure 1,2); dry waste which derives from agriculture, food and wood industries (Figure 3), humid waste which is liquid in general and not commonly reused, and finally energy crops (Figure 4), which nowadays, constitutes a large part of biomass energy production.

Energy crops are plantations that are grown for the sole purpose of producing bioenergy, more specifically biofuels.

Being a versatile source of energy, Biomass can be converted into solid, liquid and gaseous fuels. It can produce heat, electricity and transport fuels apart from having the option of being stored when not used.

The most common process to transform biomass to a usable energy source is combustion which, with the induction of large amounts of Oxygen produces heat. Heat is then used for domestic purposes (*heating, hot water and cooking*) or for industrial purposes (*steam and electricity production*).

In fact, Heat produced converts water to steam which, by the help of a turbine and a generator (*industrial*) or Sterling engine (*domestic*) can produce Electricity.

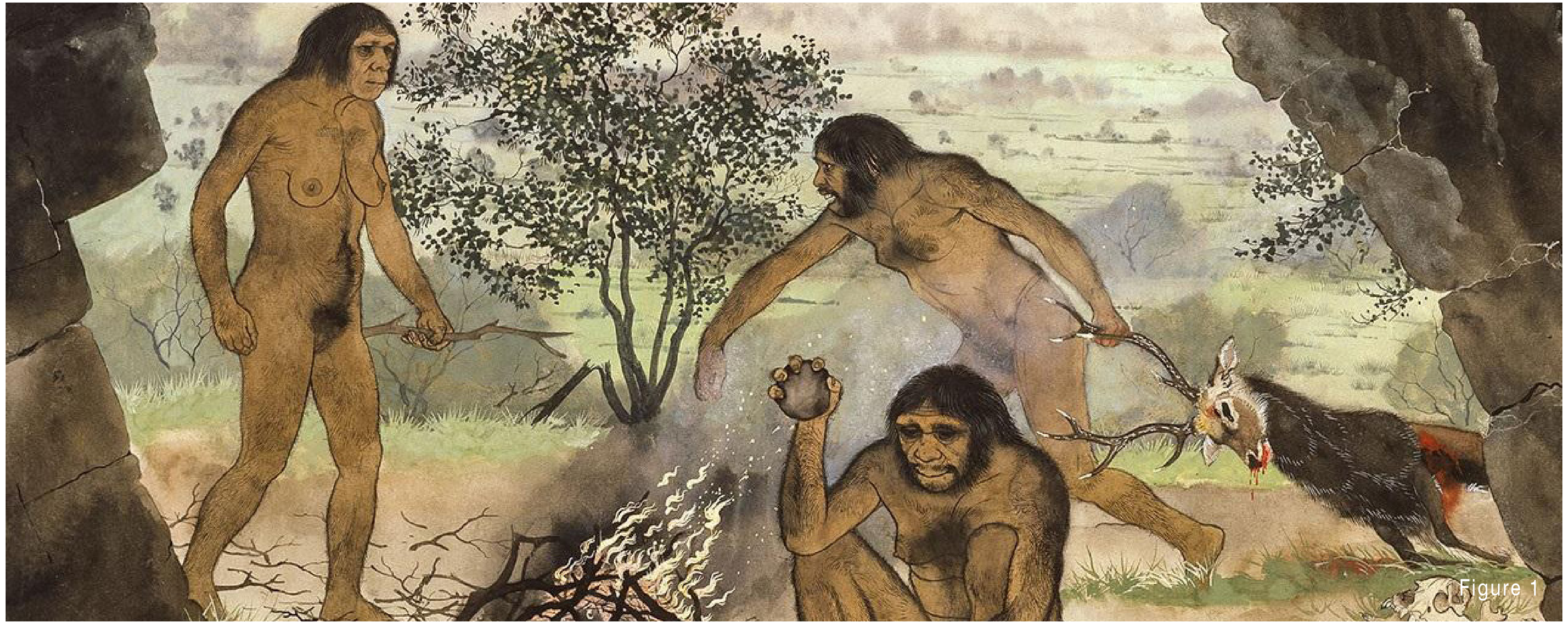

Figure 1


Figure 2


Figure 3


Figure 4

I.II. HISTORY OF BIOMASS



It wasn't before the 1970's that biomass as a name came to exist when the possibility of replacing fossil fuels interested many scientists.

In fact, before the Industrial Revolution, biomass satisfied almost all of cave-men's energy demand (*Figure 1*). Wood and charcoal were used as fuel for fires which would serve as cooking and heating.

About three-quarters of the world's renewable energy use involves bioenergy, with more than half of that consisting of traditional biomass use.

In fact, Bioenergy is divided into 2 main categories: traditional and modern.

I.II.

The traditional use of biomass refers to the use of solid biomass with basic technologies, such as a three-stone fire (*Figure 1*), often without or with poorly operated chimneys (*Figure 2*).

Mostly present in isolated areas with no access to energy, this inefficient burning of biomass results in health problems (*with smoke inhalation*), pollution, deforestation and unsafe living spaces.

After losing a lot of energy, the result is a small amount of Heat that can only be used for cooking and heating.

On the other hand, more technologically advanced solutions such as "modern" biomass stoves (*Figure 3*) improve the efficiency while reducing dangerous emissions. These stoves use less fuel and assure a better ventilation.

Modern bioenergy technologies include liquid biofuels produced from plants; bio-refineries; biogas produced through anaerobic digestion of residues; wood pellet heating systems…

Here, a small amount of energy is lost in the process and the rest can be transformed into Heat, Biofuels and Electricity used in Buildings or Industries.


Figure 1


Figure 2


Figure 3

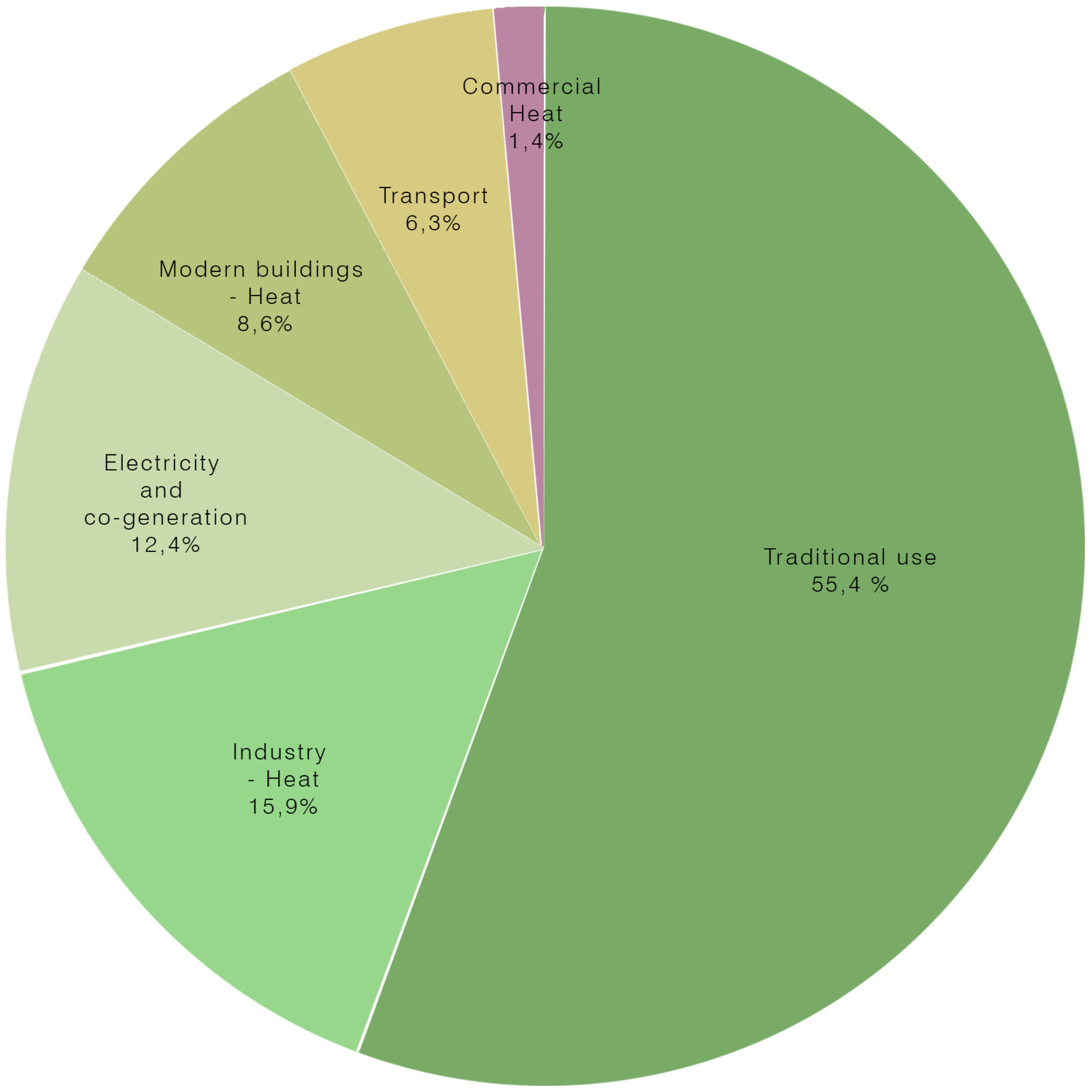
I.III. STATISTICAL STUDY OF BIOMASS

Graph. Consumption of biomass and waste resources by end use in 2015

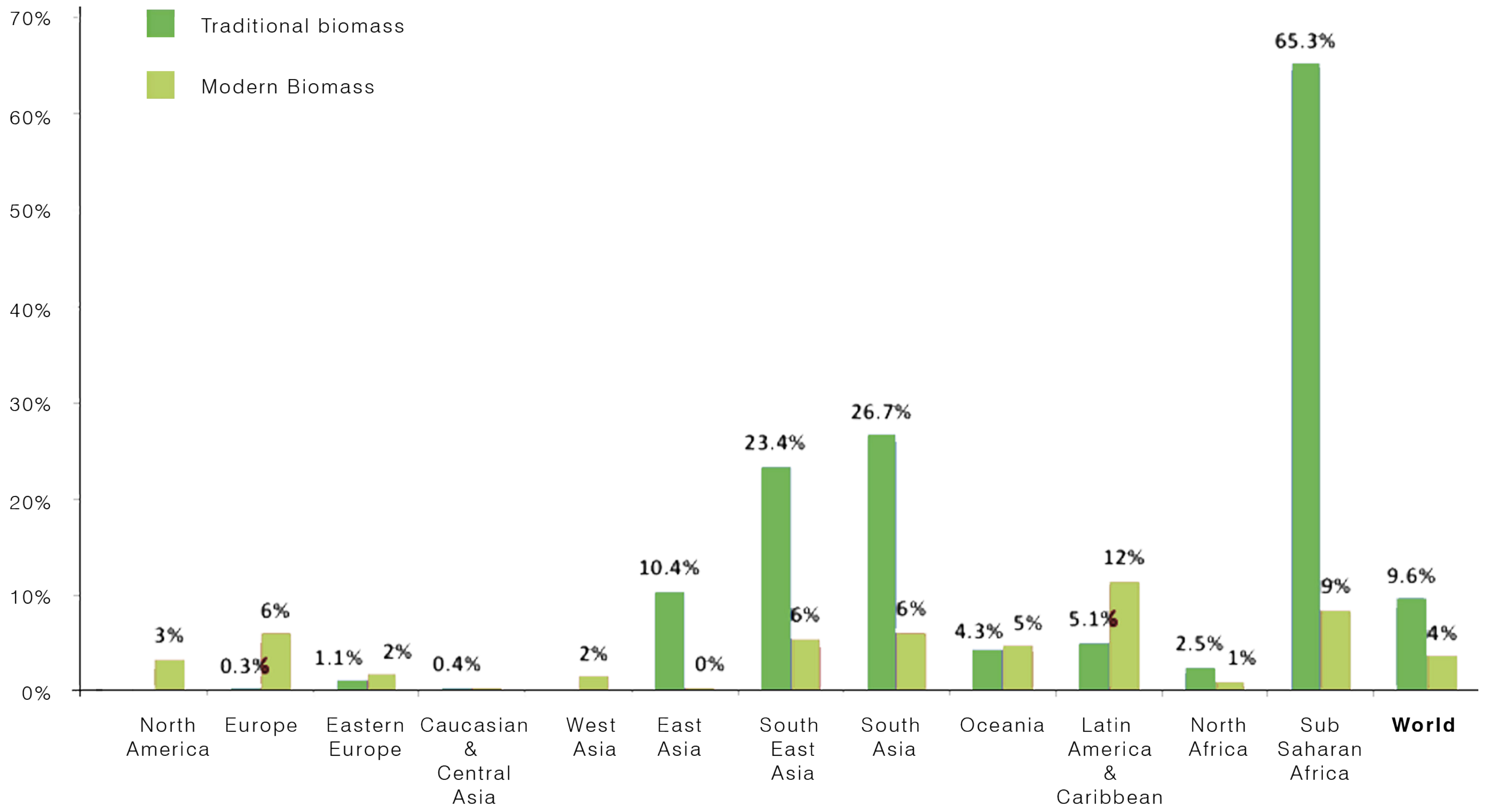
As shown in the graph on the right, 55% of Biomass is being used in a Traditional way whereas a smaller percentage is being transformed to heat used in industries.

In descending order, biomass is being transformed to Electricity and to Heat in modern buildings.

Finally, and with a smaller percentage, it is being used in the transportation sector and for commercial heat.



I.III.



Graph. Share of biomass in final energy consumption (in %) (WBA global bioenergy statistics 2015).

We can notice that in a poor areas like for example Sub Saharan Africa, 65,3% of the total energy consumption comes from traditional biomass, whereas in Europe for example, only 0.3% of energy comes from traditional biomass.

In contrast, modern biomass consumption is mostly common in countries where technology is developed. For example, in Latin America and the Caribbean (12%, the region is specialized in the production of biofuels), in Southern Asia (6%, Sugar cane bagasse is present in the region as well as wood as a raw fuel.) Finally, Europe (6%, Biofuels and biogas are produced in some countries, while in others wood is grown as a raw feedstock).

A clear contrast highlights the correlation between modern biomass consumption and the level of development and technology of the countries.

More developed countries use more responsibly Biomass, while underdeveloped exploit the resources without taking into considering the global implications on health, nature…

I.III.

Table. General characteristics of straw and wood pellets, and their respective raw materials

It is interesting to compare many biomass fuels and their characteristics. The table shows the clear advantages of wood pellets as a bio fuel.

Compared with coal, wood pellets have less moisture and produce much lower amounts of Ashes. Although having a slightly lower density and half the efficiency of coal as a fuel, they are renewable, respect the environment and are at least three times more efficient than other biomass products (*like sawdust, straw…*)

Hence, burning wood pellets would be the most efficient biomass until today.

	Density (kg/m³)	Moisture (% w.b)	Lower Heating Value (MJ/kg)	Ash (% d.m.)	Energy density (GJ/m³)
 Straw (chopped)	50	10 - 20	14.5	5	0.7
 Straw (big bales)	130	10 - 18	14.5	5	1.9
 Straw pellets	600	< 10	15	5	9
 Wood chips	250	10 - 50	11 - 17	0.5	4.3
 Sawdust	200	20 - 50	12 - 17	0.5	3.4
 Wood pellets	**650**	**< 10**	17.5	**0.5**	**11.4**
 Coal	**850**	**10 - 15**	24	**12**	**20.4**

I.IV. BIOMASS AND ARCHITECTURE

Until today, Bioenergy was frequently used in the industrial sector. However, in 2013 the 1st biomass powered building in the world opened its doors. The BIQ house, (*Figure 2*) located in Hamburg, Germany is a residential building that has a bioreactor façade where microalgae are harvested.

The sides of the cubic building that face the sun consist of a second skin composed of 129 modules which contain micro-algae. Each module is made up of a steel frame, a laminated security glass from each side and a connection to all tubes from the lower part.
Water, algae nutrients and CO2 are injected with a constant turbulence into the PBR panels – called photo bioreactors – (*Figure 1*) in order to help algae with the photosynthetic process.

Due to sunlight and a constant turbulence to avoid algae aggregation, microalgae grows inside the PBRs producing heat (*38% of efficiency vs 60-65% with a conventional solar thermal*) and biomass (*10% of efficiency vs 12-15% with a conventional PV*).

The biomass resulting from the growth is automatically co-llected through an algae separator and collected in a tempe-rature-controlled container. Then, this amount is removed to an outdoor biogas plant to produce biogas. 80% of biomass is then converted to methane.

The associated heat production of about 40ºC is reintrodu-ced to the system via the heat exchanger or stored under-ground in the geothermal boreholes.

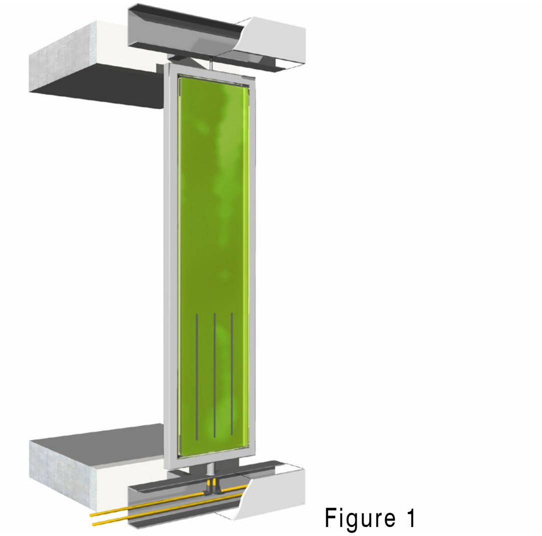


Figure 1

Figure 2

OBJECTIVE OF STUDY

PART II - OBJECTIVE OF STUDY
II.I. DELIMITATION OF AREA OF STUDY

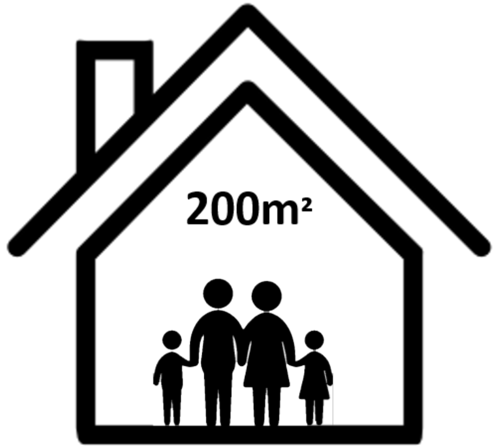
As shown in the previous section, Biomass energy has a lot of advantages, which is why I decided to implement it into architecture in a way that the facades of residential buildings can produce sufficient thermal energy for house heating and domestic hot water.

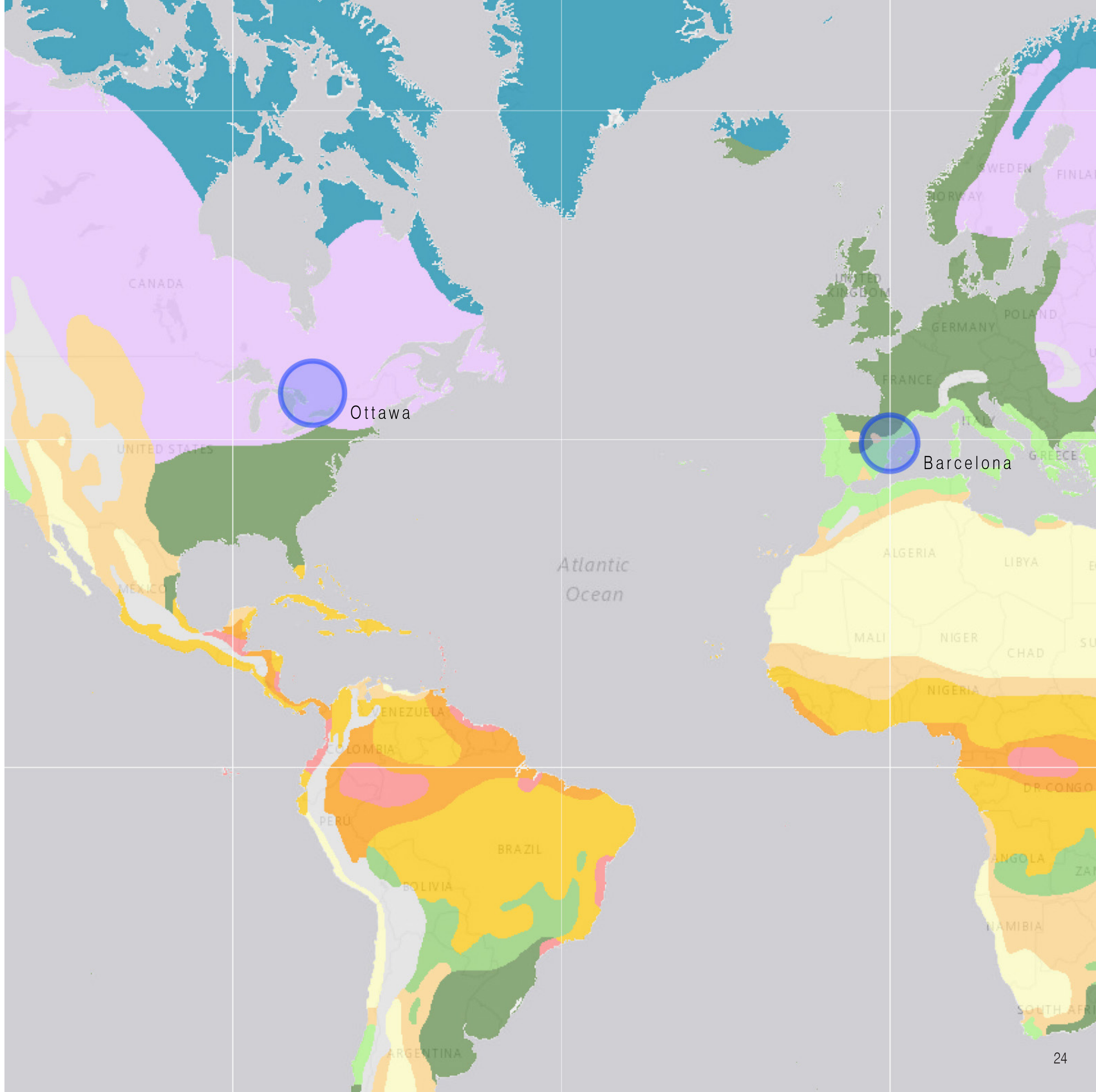
The case study is a building of 4 residential floors of 200m² each intended for a family of 4.

For the purpose of the project, 2 cities with different climates have been chosen: Barcelona, Spain and Ottawa, Canada.

Barcelona has a maritime Mediterranean climate (*Csa*) with mild winters and warm to hot summers, whereas Ottawa has a humid continental climate.

The following fragment will explain the project and will demonstrate the capacity of the proposed design to adapt to different climate zones.





II.II. DESIGN PROPOSAL

Nowadays, domestic pellet boilers (*Figure 3*) are installed in homes as independent entities. They are not good for our health, take usable space, need to be connected to the exterior facade and require maintenance. These types of boilers take oxygen from the interior space in order to help with combustion, which reduces the quantity of fresh air in homes.

About maintenance, ashes resulting from combustion need to be emptied and compartment cleaned very often. Also, the pellet container needs to be manually refilled approximately every 2 days.

The main idea is to compact the domestic pellet boilers into façades (Figure 2), creating Unitized modules.

The objective is to improve health, gain interior space, facilitate pellet automatic supply, facilitate maintenance and generate enough heat for Hot water and Heating.

Consequently, there will not be any loss of energy with transportation.

Figure 1

Figure 2

Figure 3

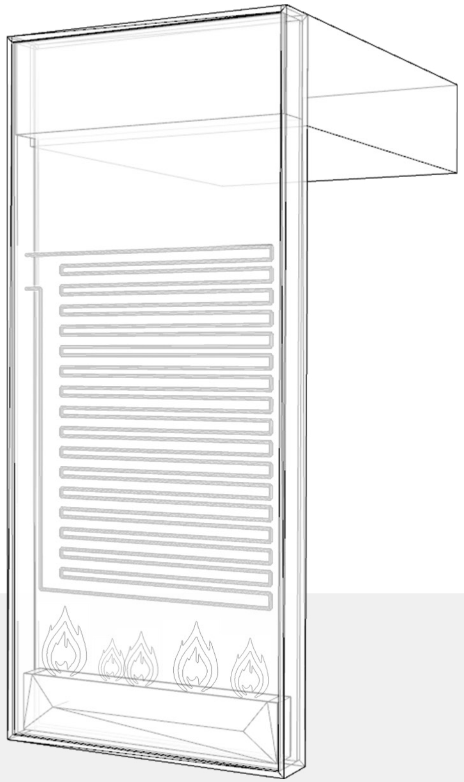
II.II.

The proposed design is a modular façade for residential buildings.
It is composed of 5 standard modules that permit to a new or existing building to produce its own thermal energy “in situ” and use it for Heating and hot water, at the same time acting as a good thermal insulator.

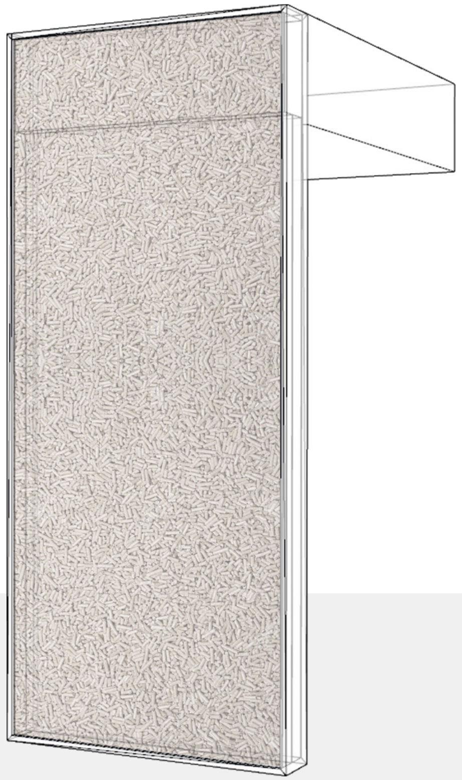
All modules are connected to each other with a smaller vertical connector module (*5*). A vertical and horizontal connection is very important to ensure flexibility in design. The system can adapt to different climates; Depending on the power needed in each city, more or less boiler modules are installed, which automatically changes the façade aesthetic.

Also, the modules can be installed in any orientation (*North, East, South, West*) given the fact that they don’t need to be exposed to sun or wind like other renewable energy generators. In fact, there are many beautiful plants that can survive in the shade like for example daylilies, hostas, Ferns ...

Compared to other energy generators, for example photovoltaics need sun light to produce electricity. Turbines need wind to produce electricity. Likewise, Algae needs light to ensure photosynthesis and produce heat and biomass, which gives a huge advantage to the modular boiler system whose generation of energy is not conditioned by climate or facade orientation (N,E,S,W).

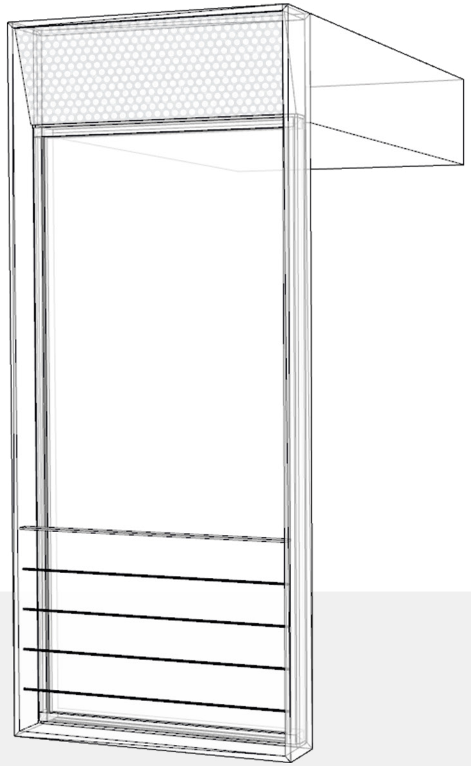


1. Boiler

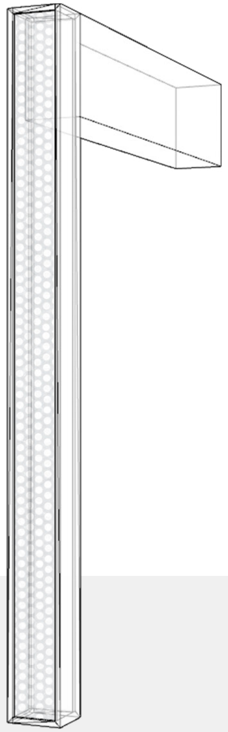


2. Pellet container

3. Plantations



4. Balcony



5. Connector

II.II.
MODULE 1

The Boiler module is a Unitized module of 1500 x 250 x 3480mm (*length, width, height*). It is anchored to the slab from the upper level. Each boiler module has a 3KW Output and is composed of an aluminum frame with thermal insulation (*Figure 1*).

At its bottom resides an ash deposit and a combustion chamber. Pellets are thrown into the fire from the sides. Right above the fire location, a serpentine tube (*Figure 2*) with anti-freeze liquid heats in a closed circuit. With a recirculation pump, the liquid goes straight to an indoor water tank where water is heated for Hot water and house heating. On both sides of the module are 5cm rock wool insulation boards with a metal sheet outside finish and a stainless steel inside finish, to reduce heat losses and increase boiler efficiency.

In its upper level, the module has an empty "box" which permit the passage of tubes from a module to another, when needed. On the box's lower part resides a water sprinkler for emergency cases. Also, a smoke extractor permits pulling out smoke during combustion.

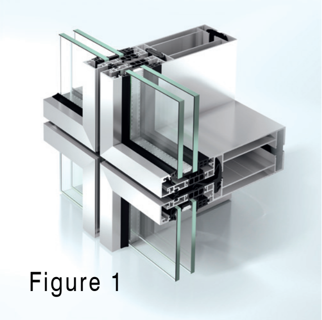
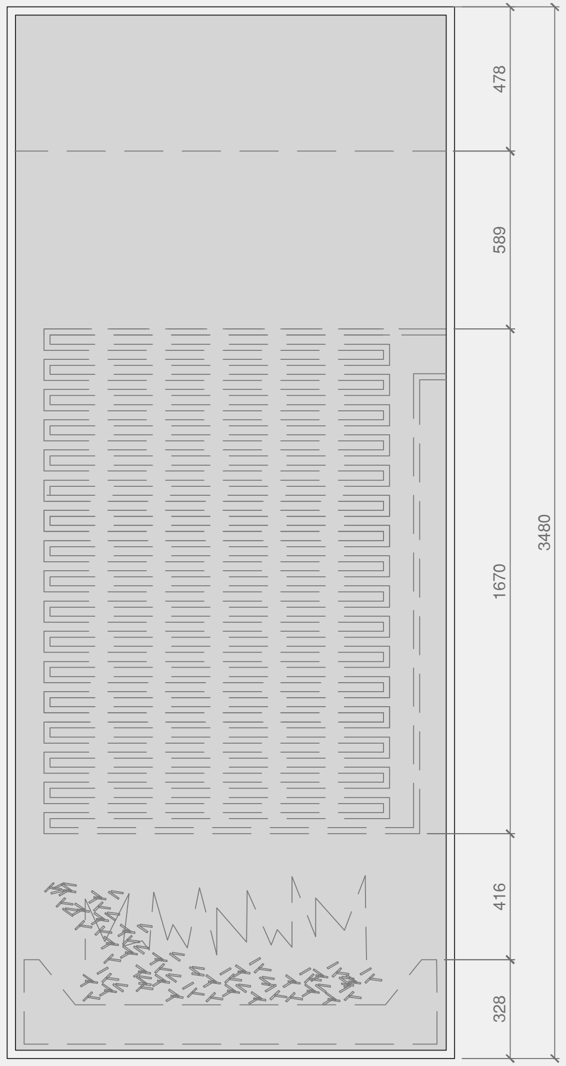
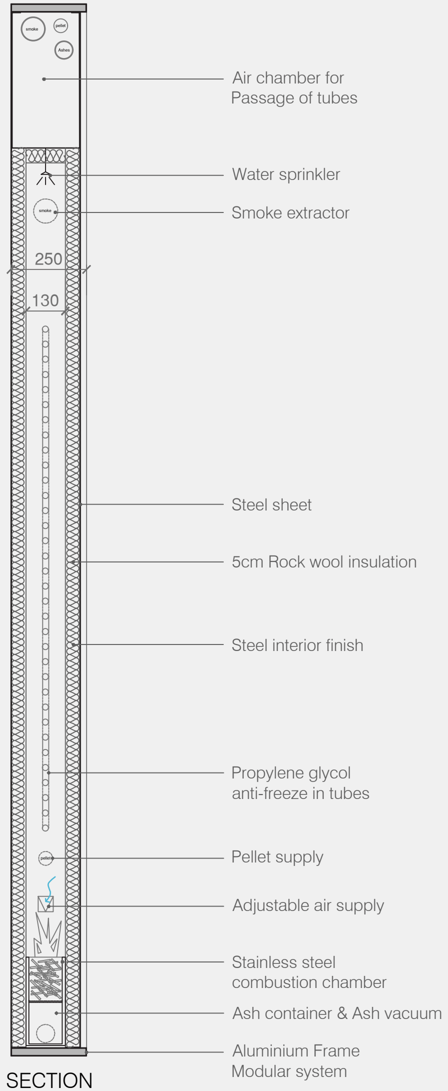


Figure 1

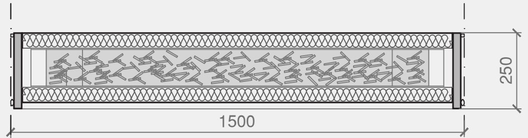

Figure 2



ELEVATION



SECTION



PLAN

scale : 1/25

II.II.
MODULE 2

The Pellet storage module is a Unitized module of 1500 x 250 x 3480mm (*length, width, height*). It is anchored to the slab from the upper level. Each pellet module is composed of an aluminum frame with thermal insulation and 2 air chambers filled with Pellets in between 6mm glass. Depending on the need, 1 or 2 chambers are filled with pellets for more or less thermal insulation.

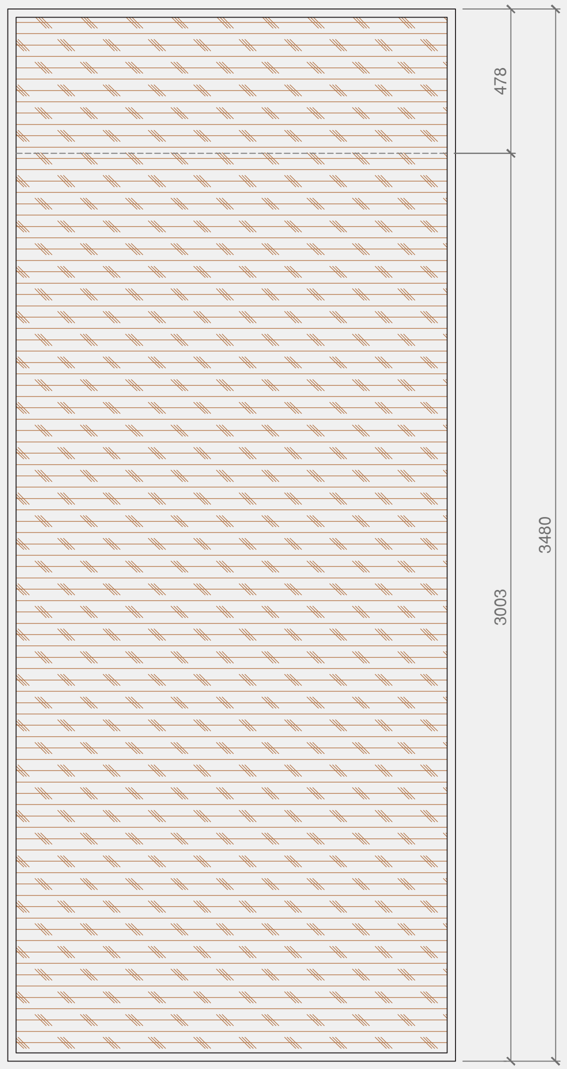
Pellets used in this case are wood pellets (*Figure 1*) made from compacted wood dust. The total volume of pellets in both chambers is 0.8m³ equivalent to 500kg. 1kg of pellet has a calorific value (*Heat released by 1kg of pellet*) of 5KWh.

The hermetic box is automatically refilled from a roof container every time pellets are burned in Module 1. Pellets are transported with flexible transport spirals that regulate the quantity of pellets that enter the modules (*Figure 2*).

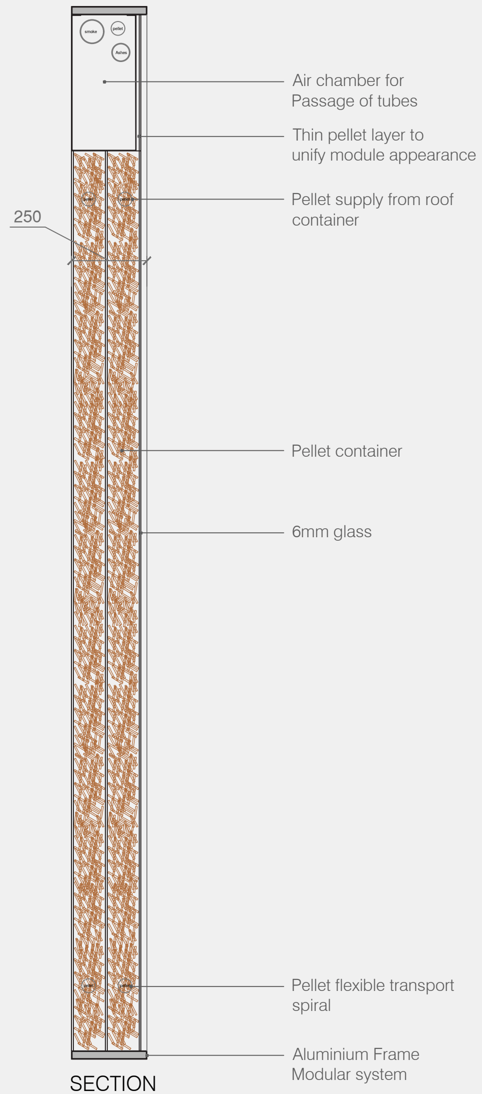
In its upper level, the module has an empty “box” which permits the passage of tubes from a module to another, when needed.

Figure 1

Figure 2



ELEVATION



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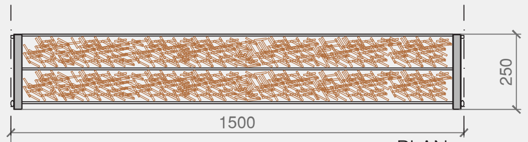

PLAN

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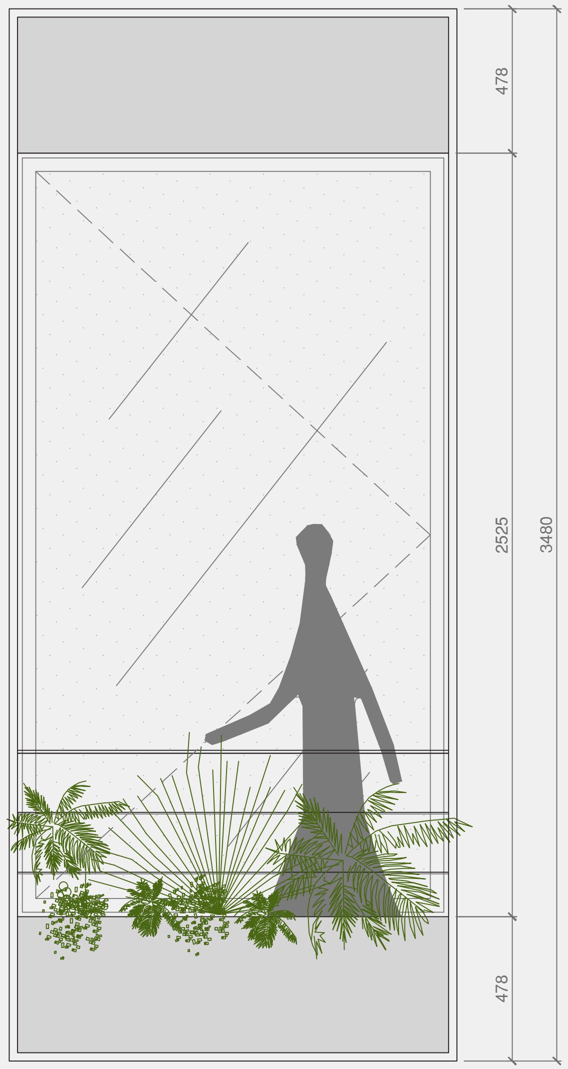
II.II.
MODULE 3

The Plant module is a Unitized module of 1500 x 250 x 3480mm (*length, width, height*). It is anchored to the slab from the upper level and is composed of an aluminum frame with thermal insulation, a plant pot, a steel handrail, an openable window and an upper chamfered box for tube circulation.

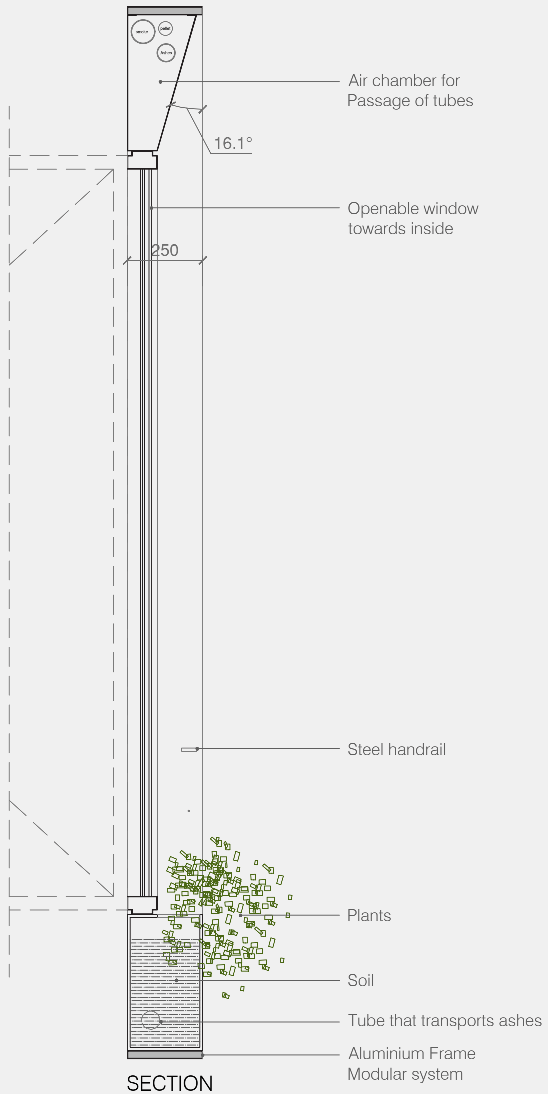
Plants receive ashes derived from pellet combustion through an ash vacuum. In fact, ashes contain calcium, potassium and phosphorus which improves fertility and texture of the soil. A temperature sensor installed in the ash deposit of module 1 permits to know when ashes have reached a certain temperature in order to be safe for transfer.

As the module is transparent, the box has a 16° chamfer to lighten the "boxy" effect that is apparent in this case.

This module was conceived for several reasons:
1st : with photosynthesis, plants clean the outside air around the house, which compensates for the smoke resulting from pellet combustion.
2nd : Ashes resulting from combustion can be reused for a good purpose, thus zero waste.
3rd : Natural ventilation needed in a residential building.



ELEVATION



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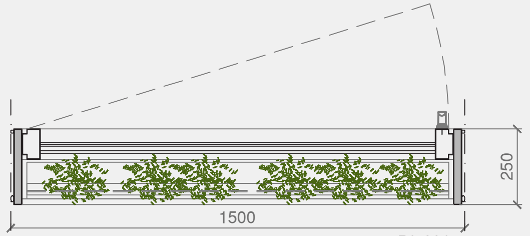

PLAN

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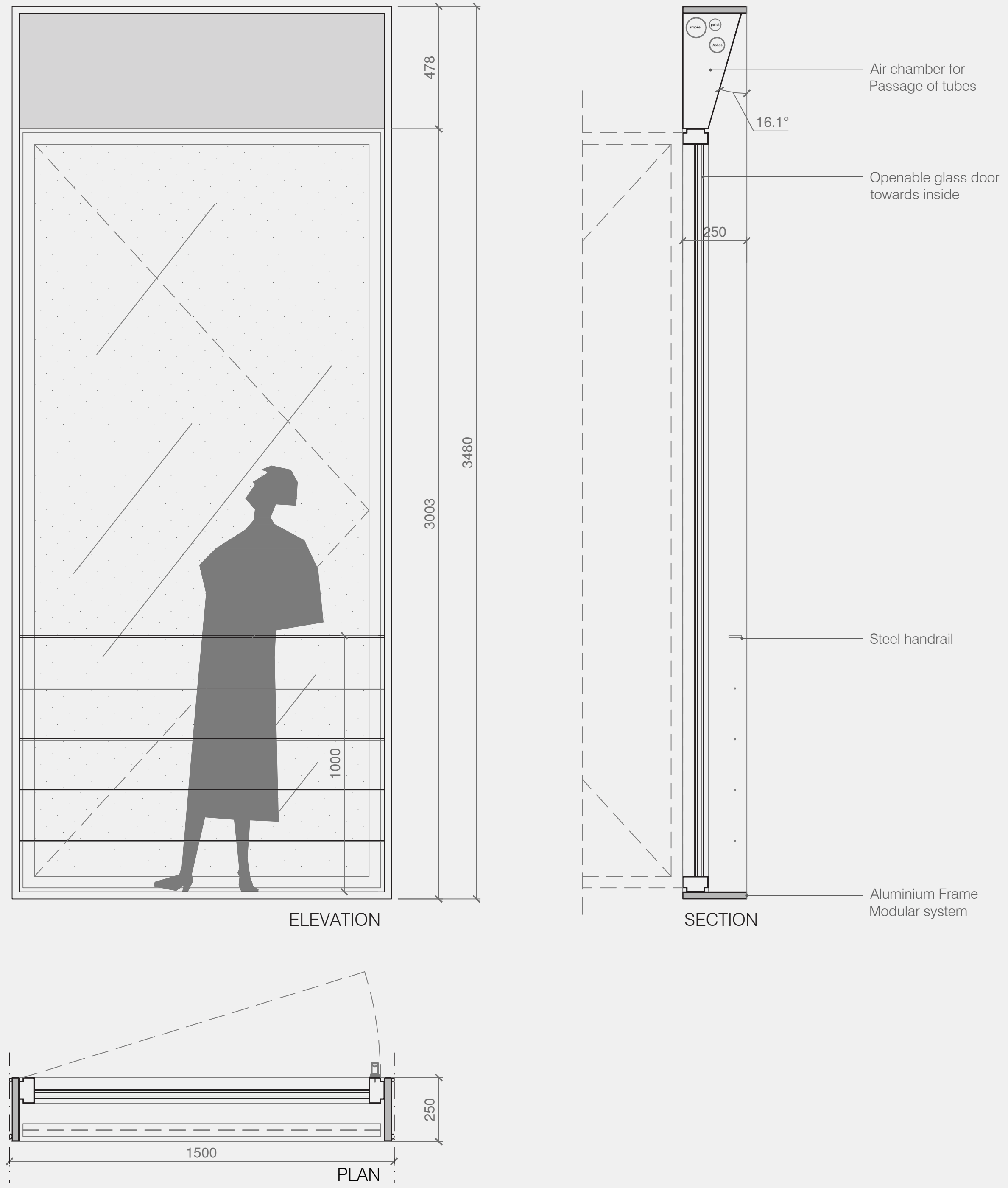
II.II.
MODULE 4

The Balcony module is a Unitized module of 1500 x 250 x 3480mm (*length, width, height*). It is anchored to the slab from the upper level and is composed of an aluminum frame with thermal insulation, a steel handrail, an openable glass door and an upper chamfered box for tube circulation.

This module helps getting light and fresh air into the house.

As the module is transparent, the box has a 16° chamfer to lighten the "boxy" effect that is apparent in this case.



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II.II.
MODULE 5

The connector module is a Unitized module of 300 x 250 x 3480mm (*length, width, height*). It is anchored to the slab from the upper level and is composed of an aluminum frame with thermal insulation and a perforated metal sheet (*Figure 1*) from the outside, for air circulation. It is completely opaque and insulated from the inside.

From the upper and lower parts, the module has holes for the vertical circulation of tubes. On its sides, on the "box" level, the box has holes for the passage of tubes. All holes are sealed if not used.

The connector is where all tubes circulate. In fact, it permits :

- Passage of pellets from roof to module 2
- Extraction of smoke from module 1
- Entrance of Oxygen to module 1
- Passage of Ashes from module 1 to module 3
- Transfer of pellets from module 2 to module 1

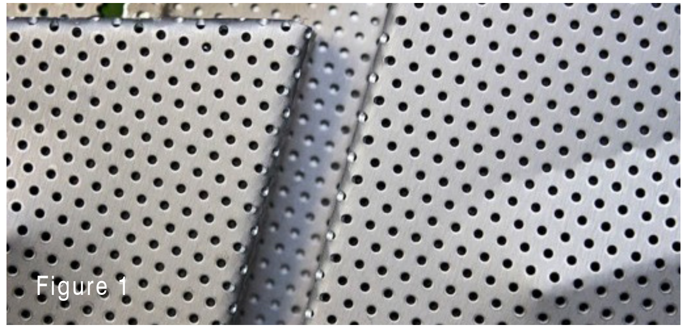
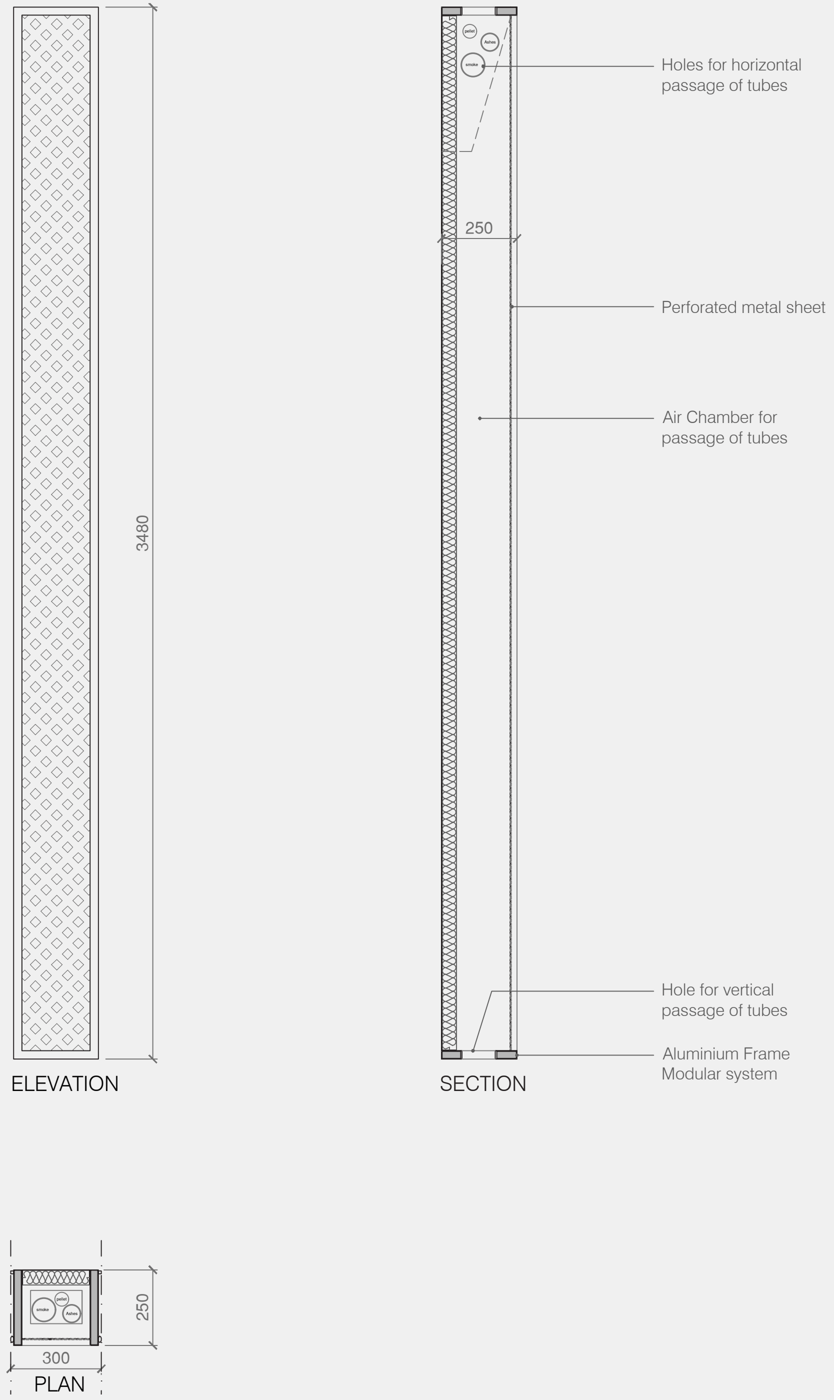


Figure 1



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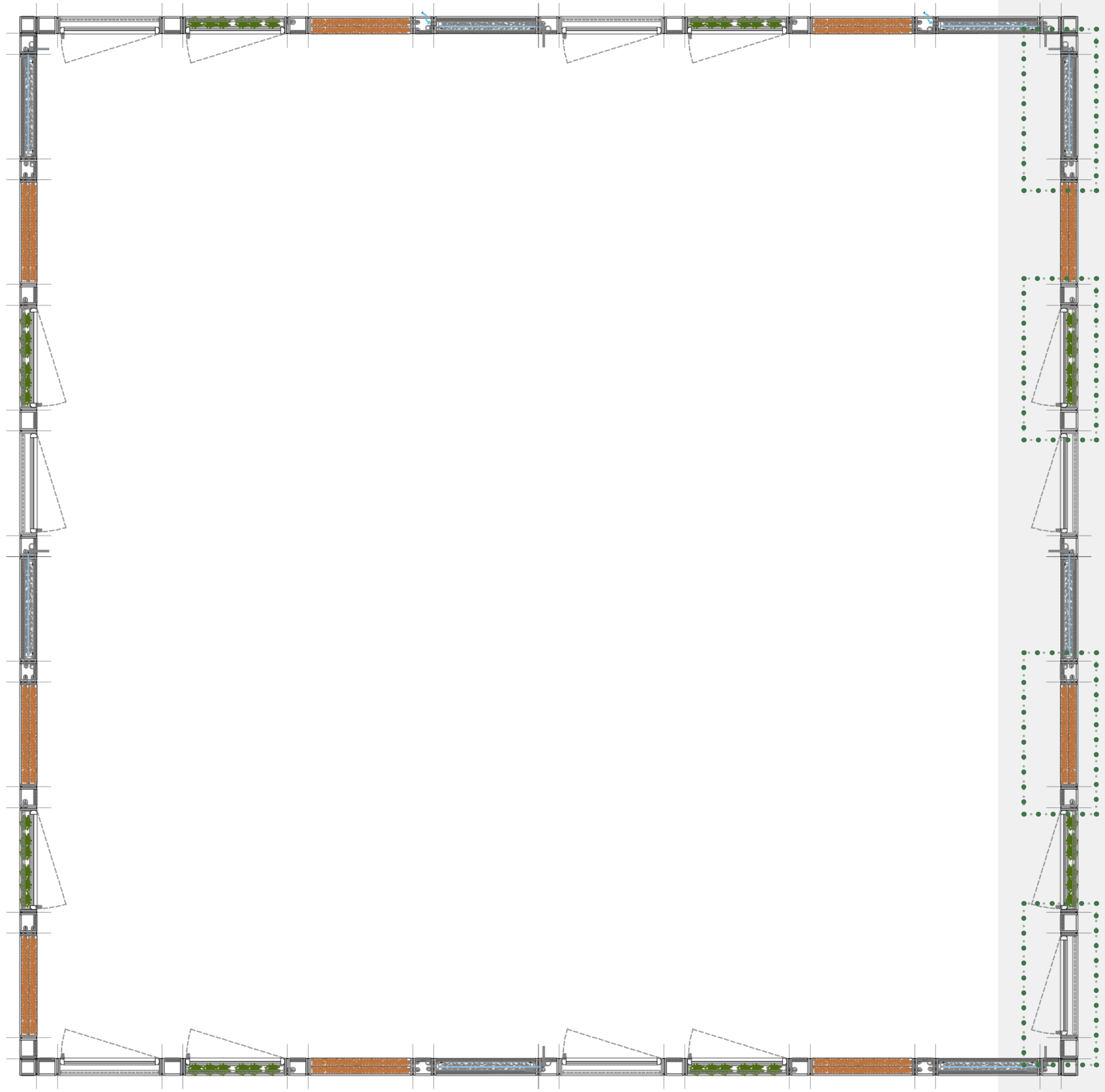
II.II.

CASE STUDY : 200M2 APARTMENT - Modular system performance



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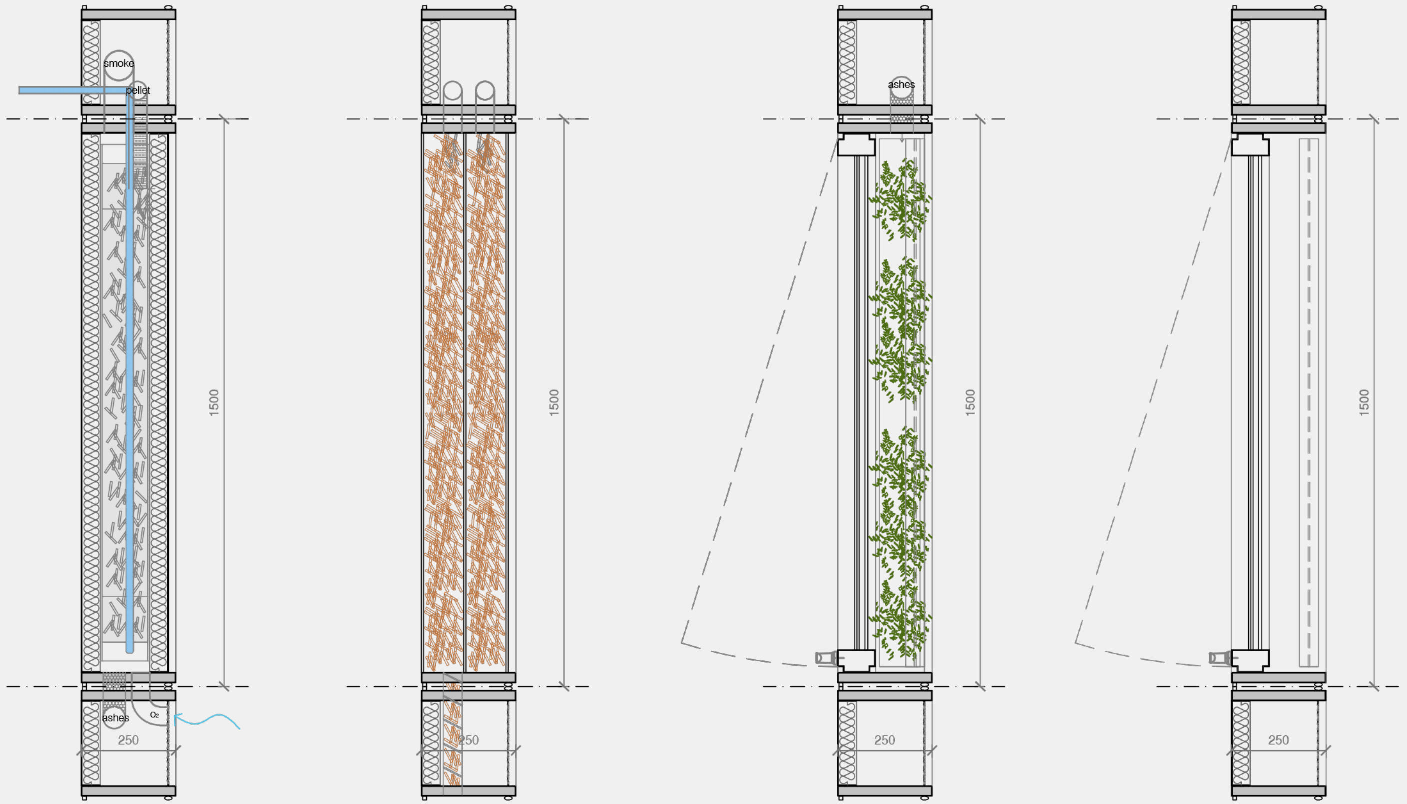

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II.II.
MODULAR SYSTEM PERFORMANCE

Each floor works independently, which means that if the 3rd floor tenants are away for vacation, the boiler modules on that floor don't function. It is important to say that the quantities of each module on each floor depends on tenant's need of heat. Arrows in the elevation on the right explain the circulation of tubes and substances within the vertical and horizontal circulation areas of the façade.

Pellets are transported from a roof deposit to all Modules 2 (*with a flexible transport spiral for pellets*). Roof container is hermetic and gets filled every month to ensure that all pellet modules are always full and ready to be burned.

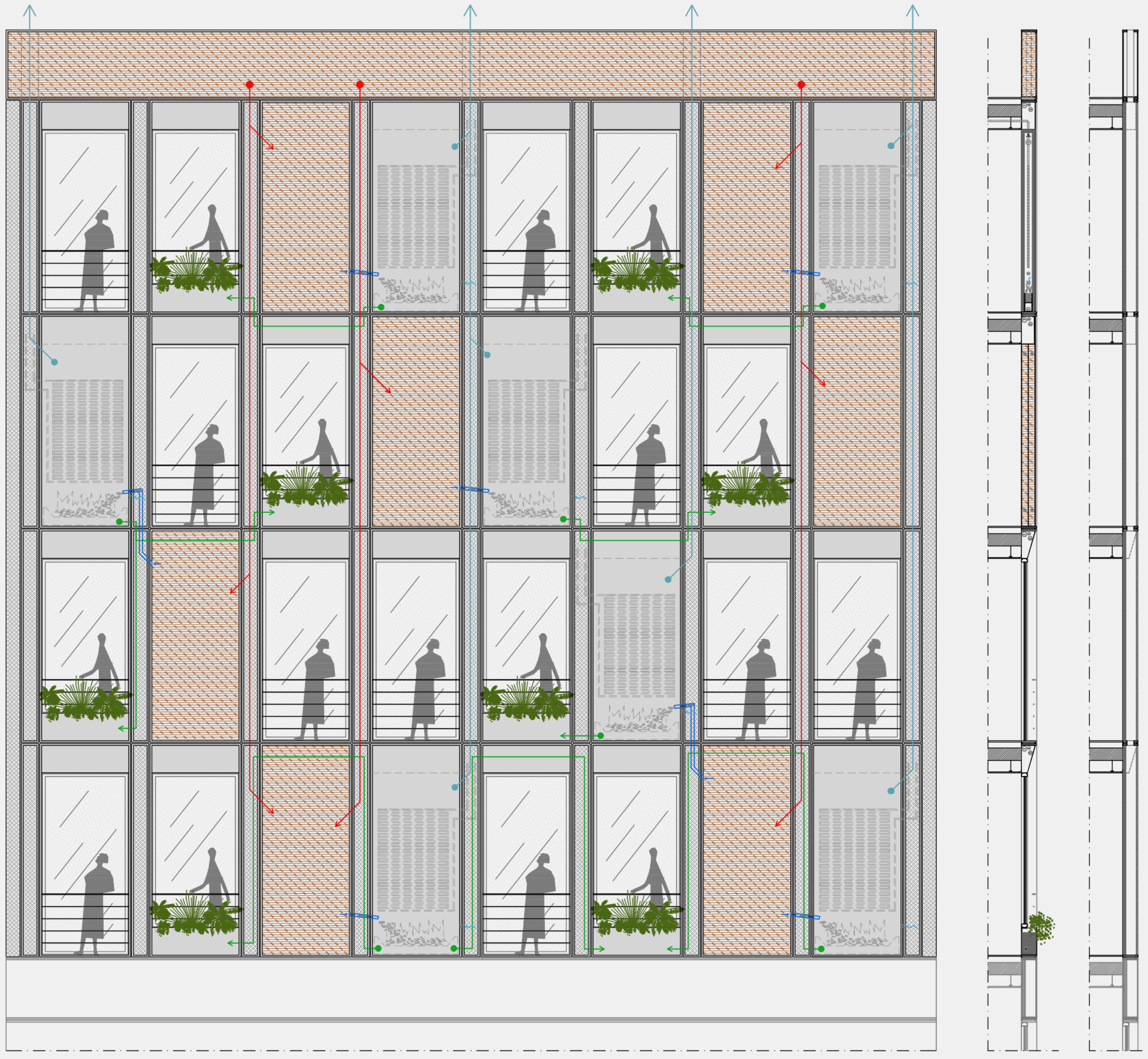
Pellets are transported (*with a flexible transport spiral for pellets*) from Modules 2 to the boiler modules, when hot water or heating is needed.

Antifreeze circulates in tubes in a closed circuit heating the interior water tank. Tubes pass through the connector and straight through the false ceiling to the water tank.

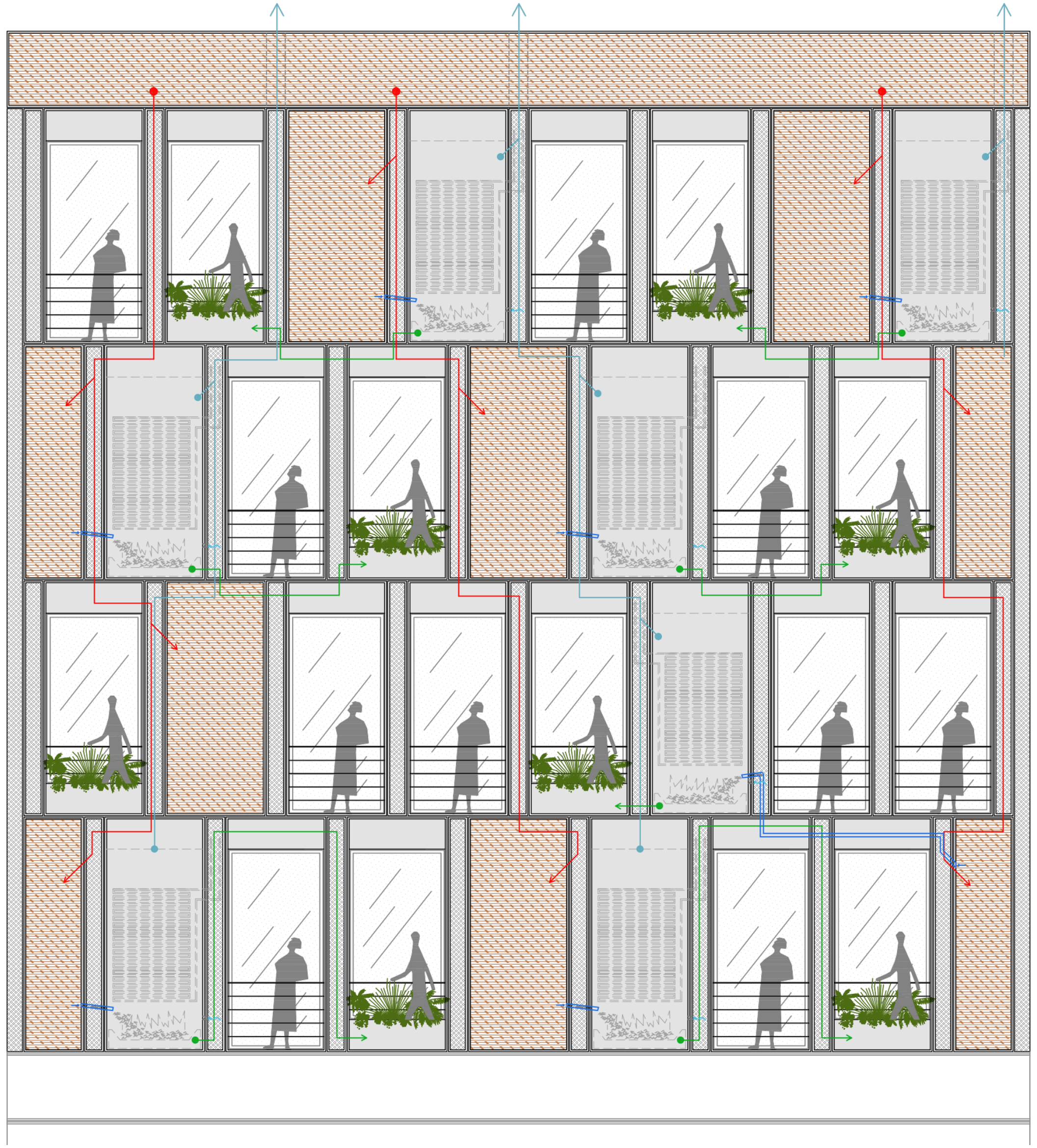
Smoke resulting from pellet combustion goes through an extractor straight to the roof.

Ashes resulting from pellet combustion are vacuumed into the soil of module 3 after cooling down and drying.

Oxygen is absorbed with a vacuum into the boiler for combustion.

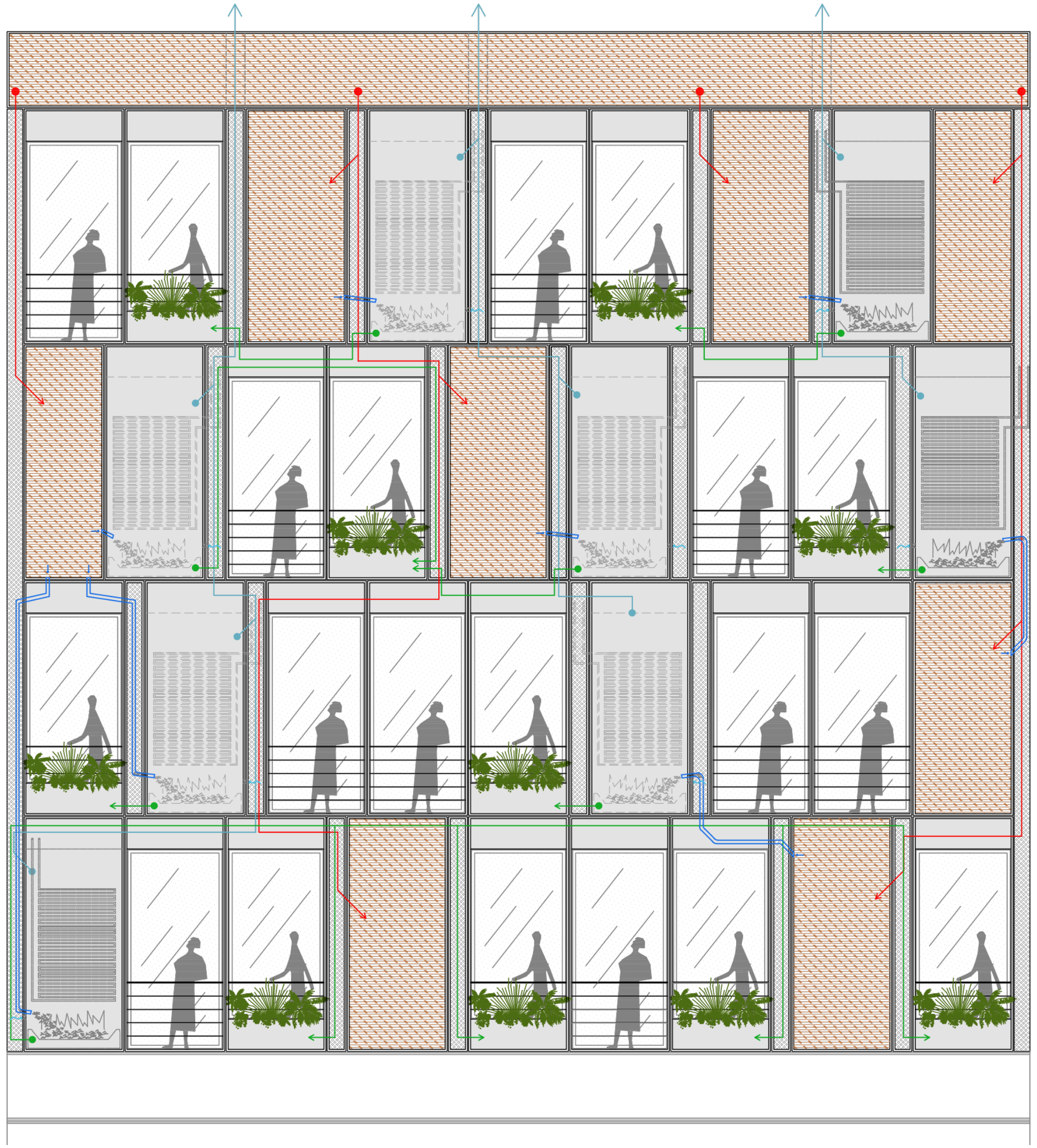


II.II.
DESIGN ALTERNATIVES



Alternative 1.

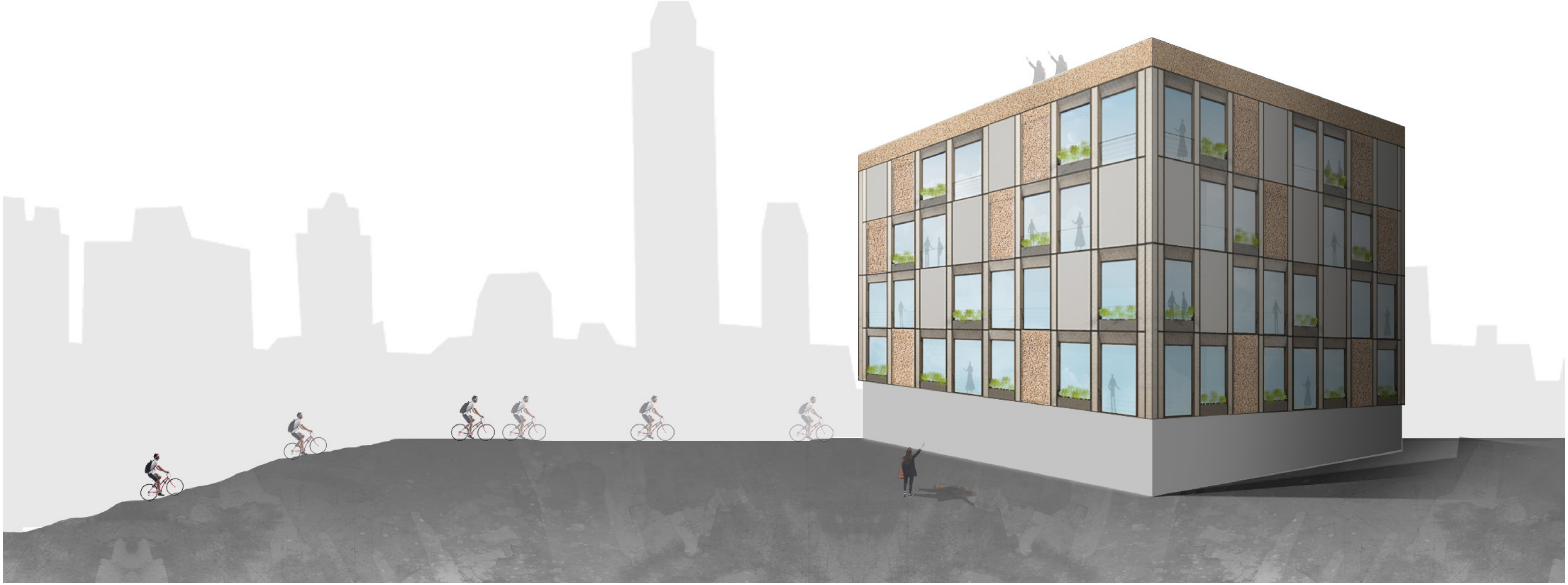
More flexibility,
Modules are not aligned on a vertical axis. In this case, the horizontal connections are used more in order to help tube passage.



Alternative 2.

Optimizing the modules to the maximum,
Connectors are taken out when not used, which permits to add more modules on each floor and get more light into the apartments.

II.II.
SIMULATION



II.III. STUDY & ANALYSIS OF INNOVATION BEHAVIOR

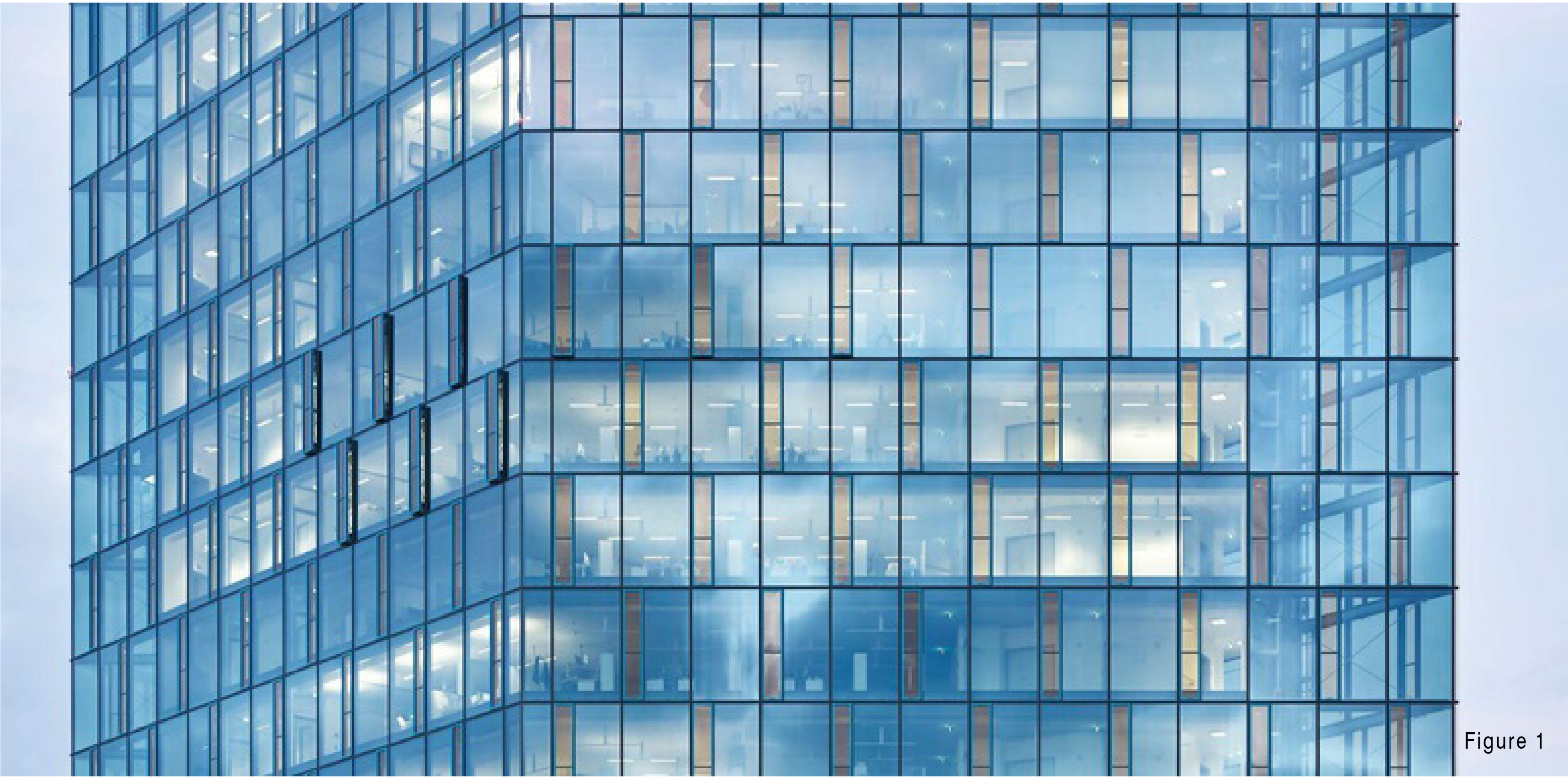


Figure 1

Nowadays, the trend in architecture facades is moving towards prefabricated modular elements (Figure 1) which are assembled in the workshop and then mounted with a crane : better quality, faster, more efficient installation.

Worldwide, a lot of towers are made up of fully modular glazed facades which have a bad thermal behavior. In some countries, this may work but in others like for example, Dubai, where it is very hot all year long, glass is not the best façade material. The proposed design is a reaction to all these high-rise buildings which are built without taking into consideration the city's climate.

Considering the heat generating façade: In a city with a cold climate, heat output needed for Hot water and Heating is higher than the one needed in a city with a hot weather. Same for summer and winter.

Hence, adding boiler modules in some locations while diminishing the number of transparent modules could be a great way to adapt a same modular system to different countries.

II.III.
COMPARISON BARCELONA - OTTAWA

For the study, two cities with opposite climates were chosen : Barcelona and Ottawa.

Also, the study considers a 200m² apartment for 4 people.

Let's start by the Module 1 : The total Output (KW) needed for Heating and Hot water differs for both countries in summer and winter. In fact, in summer boilers are only used for Hot water, whereas in winter boilers are also used for Heating the house.

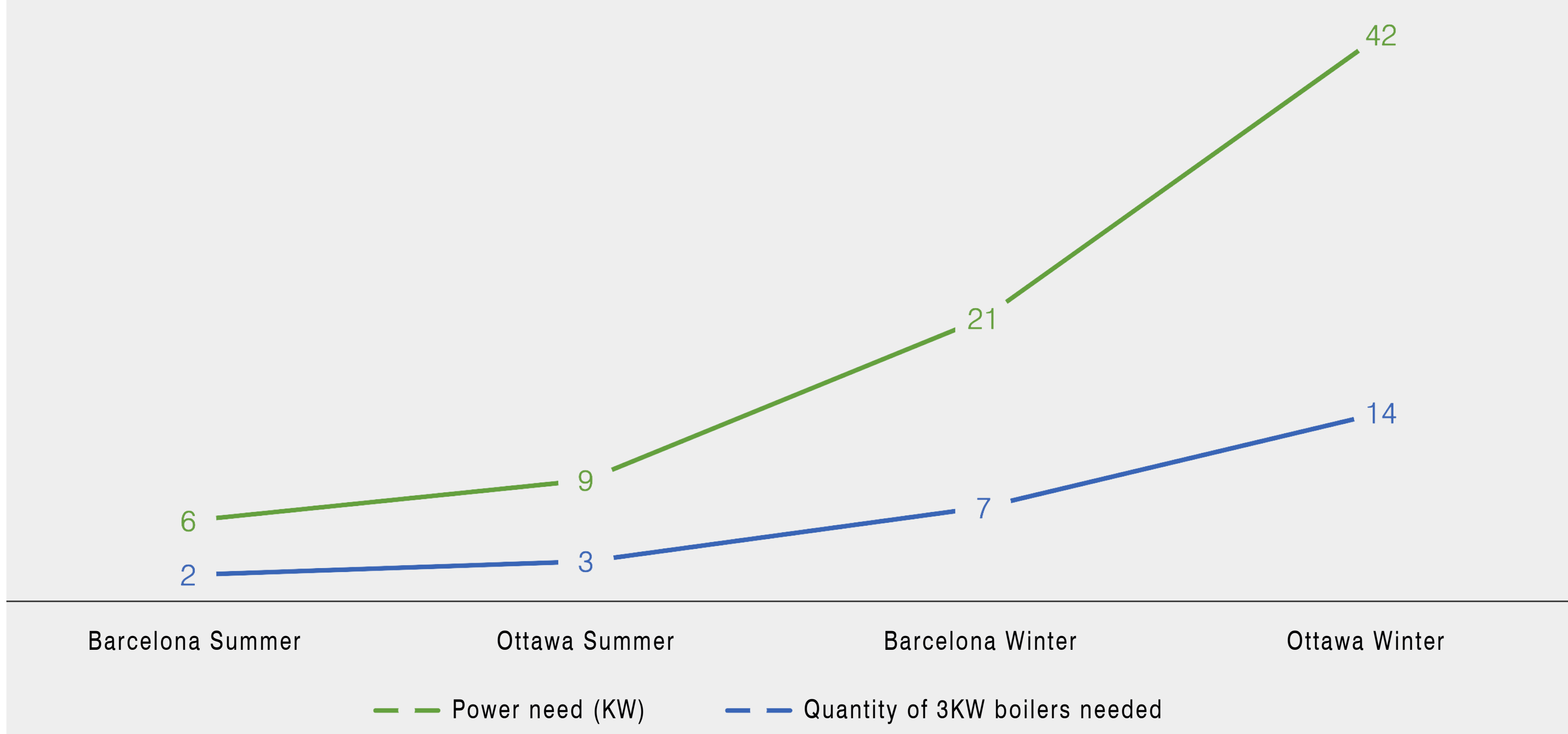
Barcelona	Winter	21 KW
	Summer	6 KW
Ottawa	Winter	42 KW
	Summer	9 KW

Considering that each Boiler module has a 3KW capacity, this means that the apartment will need :

Barcelona	Winter	7 boilers
	Summer	2 boilers
Ottawa	Winter	14 boilers
	Summer	3 boilers

To summarize it all, the family of 4 in Barcelona will need 7 boilers installed, from which only 2 will be used in summer.

As for the family in Ottawa, they will need 14 boilers installed, from which only 3 will be used in summer.



II.III.
COMPARISON BARCELONA - OTTAWA

Considering the Module 2, a cold climate would need more layers of pellets than a hot climate in order to thermally insulate better the house.

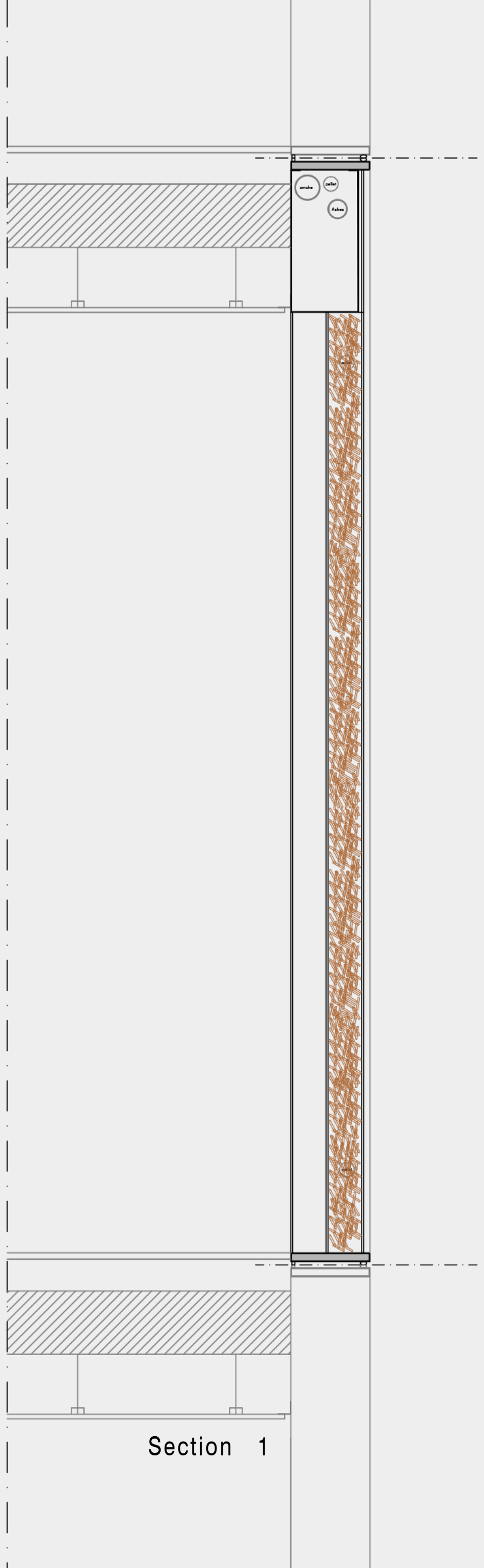
Barcelona	Triple Glazing with 2 air chambers of 10cm each. 1 of them filled with pellets. Umodule = 0.78
Ottawa	Triple Glazing with 2 air chambers of 10cm each. Both filled with pellets. Umodule = 0.49

U-values measure how effective a material is as an insulator. The lower the number is, the better the material insulates. 0.49 is a U value that is asked in highly energetic buildings. In Ottawa the temperatures drop a lot, therefore it is important to better insulate.

Depending on the energy standards asked, in Barcelona a 0.78 is very good considering the city doesn't have an extreme weather. But of course, if a better Uvalue is asked for, the 2 chambers will be filled.

Also, 1 chamber filled with pellets will of course be less opaque than 2 full chambers.

The Sections on the right show the difference between what would Barcelona (*Section 1*) or Ottawa's (*Section 2*) pellet module look like.



Section 1

Section 2

II.III.
COMPARISON BARCELONA - OTTAWA

Considering the Module 3, plants that survive in Ottawa are of course not the same as the ones that survive in Barcelona.

Talking about hardiness zones, Barcelona is located in the Hardiness Zone 10a, whereas Ottawa is located in Zone 5a.

Hardiness zones determine a geographic area defined to incorporate a certain range of climatic conditions relevant to plant growth and survival.

Also, as the modular façade can be installed in all 4 cardinal directions (*North, East, South, West*), on the right are some shade plants that can survive in each one of the 2 hardiness zones.

Colors and textures are existent even for plants that survive in the shade.

BARCELONA, 10a

OTTAWA, 5a


Japanese forest grass


Hosta


Bleeding heart


Astilbe


Fern


Hellebore

II.III.
COMPARISON BARCELONA - OTTAWA

As displayed in the part II.II, there are different alternatives to the standard modulation.

Below, the Uglobal of 2 options will be calculated :

<u>1st option - Standard modulation :</u> 1 module + 1 connector + 1 module + 1 connector….

	Module	Uvalue/module	Quantity	Uvalue	Justification
32	Boiler	0.36	7	2.52	Number of boilers 7 x 3KW = 21KW, for maximum consumption in winter
	Pellet, 2 air chambers	0.78	10	7.8	Triple Glazing with 2 air chambers of 10cm each. 1 of them filled with pellets
	Plant	1.05	10	10.5	Double glazing with argon + any Plant that can survive the Hardiness Zone 10a of Barcelona climate
	Balcony	1.05	5	5.25	Double glazing with argon + aluminium insulating frame
	Connector	0.81	36	29.16	Number of intermediate modules depends on appearance of the whole bldg.
Uglobal Barcelona				0.81	

	Module	Uvalue/module	Quantity	Uvalue	Justification
32	Boiler	0.36	14	5.04	Number of boilers 14 x 3KW = 42KW, for maximum consumption in winter
	Pellet, 2 air chambers	0.49	10	4.9	Triple Glazing with 2 air chambers of 10cm each. 2 of them filled with pellets
	Plant	1.05	5	5.25	Double glazing with argon + any Plant that can survive the Hardiness Zone 5a of Ottawa climate
	Balcony	1.05	3	3.15	Double glazing with argon + aluminium insulating frame
	Connector	0.81	36	29.16	Number of intermediate modules depends on appearance of the whole bldg.
Uglobal Ottawa				0.70	

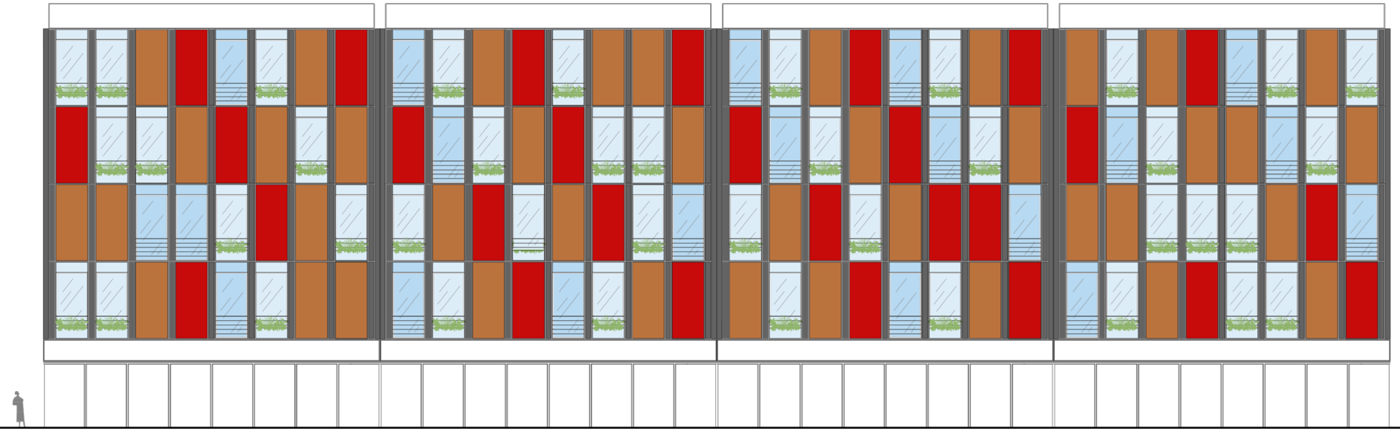
II.III.

COMPARISON BARCELONA - OTTAWA

Below is how a building would look like in Barcelona vs Ottawa, having the number of modules per floor, as cited in the tables. (*Standard modulation taken into account*)

Modules,
Total: 32/floor

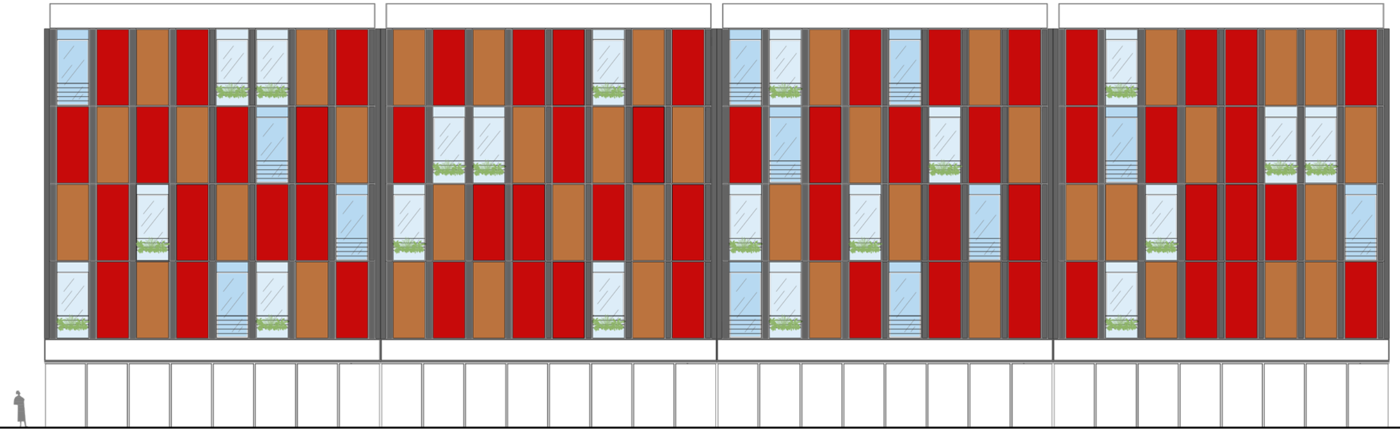
7	Boiler, 3kW each
10	Pellet, 1 air chamber filled
10	Plant, zone 10a
5	Balcony
36	Connector



BARCELONA, Uglobal = 0.81

Modules,
Total: 32/floor

14	Boiler, 3kW each
10	Pellet, 2 air chambers filled
5	Plant, zone 5a
3	Balcony
36	Connector



OTTAWA, Uglobal = 0.70

II.III.
COMPARISON BARCELONA - OTTAWA

2nd option - Alternative 2 modulation : Optimized modulation, less connectors & more pellet modules.

In fact, compared to 1st standard option, when some connectors are removed to optimize the circulation of tubes, more modules (*1-2-3-4*) can fit : 36 modules instead of 32 in the 1st option.

	Module	Uvalue/module	Quantity	Uvalue	Justification
36	Boiler	0.36	7	2.52	Number of boilers 7 x 3KW = 21KW, for maximum consumption in winter
	Pellet, 2 air chambers	0.78	14	10.92	Triple Glazing with 2 air chambers of 10cm each. 1 of them filled with pellets
	Plant	1.05	10	10.5	Double glazing with argon + any Plant that can survive the Hardiness Zone 10a of Barcelona climate
	Balcony	1.05	5	5.25	Double glazing with argon + aluminium insulating frame
	Connector	0.81	18	14.58	Number of intermediate modules depends on appearance of the whole bldg.
Uglobal Barcelona				0.81	

	Module	Uvalue/module	Quantity	Uvalue	Justification
36	Boiler	0.36	14	5.04	Number of boilers 14 x 3KW = 42KW, for maximum consumption in winter
	Pellet, 2 air chambers	0.49	14	6.86	Triple Glazing with 2 air chambers of 10cm each. 2 of them filled with pellets
	Plant	1.05	5	5.25	Double glazing with argon + any Plant that can survive the Hardiness Zone 5a of Ottawa climate
	Balcony	1.05	3	3.15	Double glazing with argon + aluminium insulating frame
	Connector	0.81	18	14.58	Number of intermediate modules depends on appearance of the whole bldg.
Uglobal Ottawa				0.65	

II.III.
COMPARISON BARCELONA - OTTAWA

All in all, it is clear to say that in Barcelona adding pellet modules (*which have only 1 pellet filled chamber and a relatively high Uvalue*) while diminishing the number of connectors (*from 36 to 18*) doesn't affect the Uglobal.

Whereas in Ottawa, adding pellet modules (which have 2 chambers filled with pellets and a lower Uvalue than the 1 pellet filled chamber) while diminishing the number of connectors (from 36 to 18) affects the Uglobal with better results.

	Module	Uvalue/module	Quantity	Uvalue
	Boiler	0.36	7	2.52
32	Pellet, 2 air chambers	0.78	10	7.8
	Plant	1.05	10	10.5
	Balcony	1.05	5	5.25
	Connector	0.81	36	29.16
	Uglobal Barcelona			0.81

1st option : Standard modulation

	Module	Uvalue/module	Quantity	Uvalue
	Boiler	0.36	7	2.52
36	Pellet, 2 air chambers	0.78	14	10.92
	Plant	1.05	10	10.5
	Balcony	1.05	5	5.25
	Connector	0.81	18	14.58
	Uglobal Barcelona			0.81

2nd option : Alternative 2 modulation

	Module	Uvalue/module	Quantity	Uvalue
	Boiler	0.36	14	5.04
32	Pellet, 2 air chambers	0.49	10	4.9
	Plant	1.05	5	5.25
	Balcony	1.05	3	3.15
	Connector	0.81	36	29.16
	Uglobal Ottawa			0.70

1st option : Standard modulation

	Module	Uvalue/module	Quantity	Uvalue
	Boiler	0.36	14	5.04
36	Pellet, 2 air chambers	0.49	14	6.86
	Plant	1.05	5	5.25
	Balcony	1.05	3	3.15
	Connector	0.81	18	14.58
	Uglobal Ottawa			0.65

2nd option : Alternative 2 modulation

CONCLUSIONS

Nowadays, technology is ever evolving and has even reached architecture, as energy generators are now integrated in facades. For example, in many developed countries, we can already witness this transition as photovoltaic panels and wind turbines are being installed in many buildings for electricity generation. Whereas the integration of microalgae harvesting in facades produces heat and biomass.

Biomass energy represents 14% of the world's energy production with only 1.4% used for commercial heat, which leads to the theme of this research. In fact, the book examines the possibility of integrating biomass heat production into residential building facades. Results show that it is possible to produce heat within facades through Unitized modules that incorporate small pellet boilers.

The proposed design has many advantages: it is compact, permits flexibility in design, is symbolically sustainable, has a very good thermal transmittance, can be installed in all cardinal directions an d in different climates and requires minimum maintenance. On top of that, its high efficiency is capable of generating enough thermal energy for domestic heating and hot water for a 200 m^2 apartment with a family of 4.

In the future, biomass has the potential to provide a cost-effective and sustainable supply of energy, while at the same time helping countries in meeting their greenhouse gas reduction targets.

Taking into consideration the proven potential of biomass, we can ask ourselves whether governments would eventually encourage commercial buildings to generate their own thermal energy from biomass.

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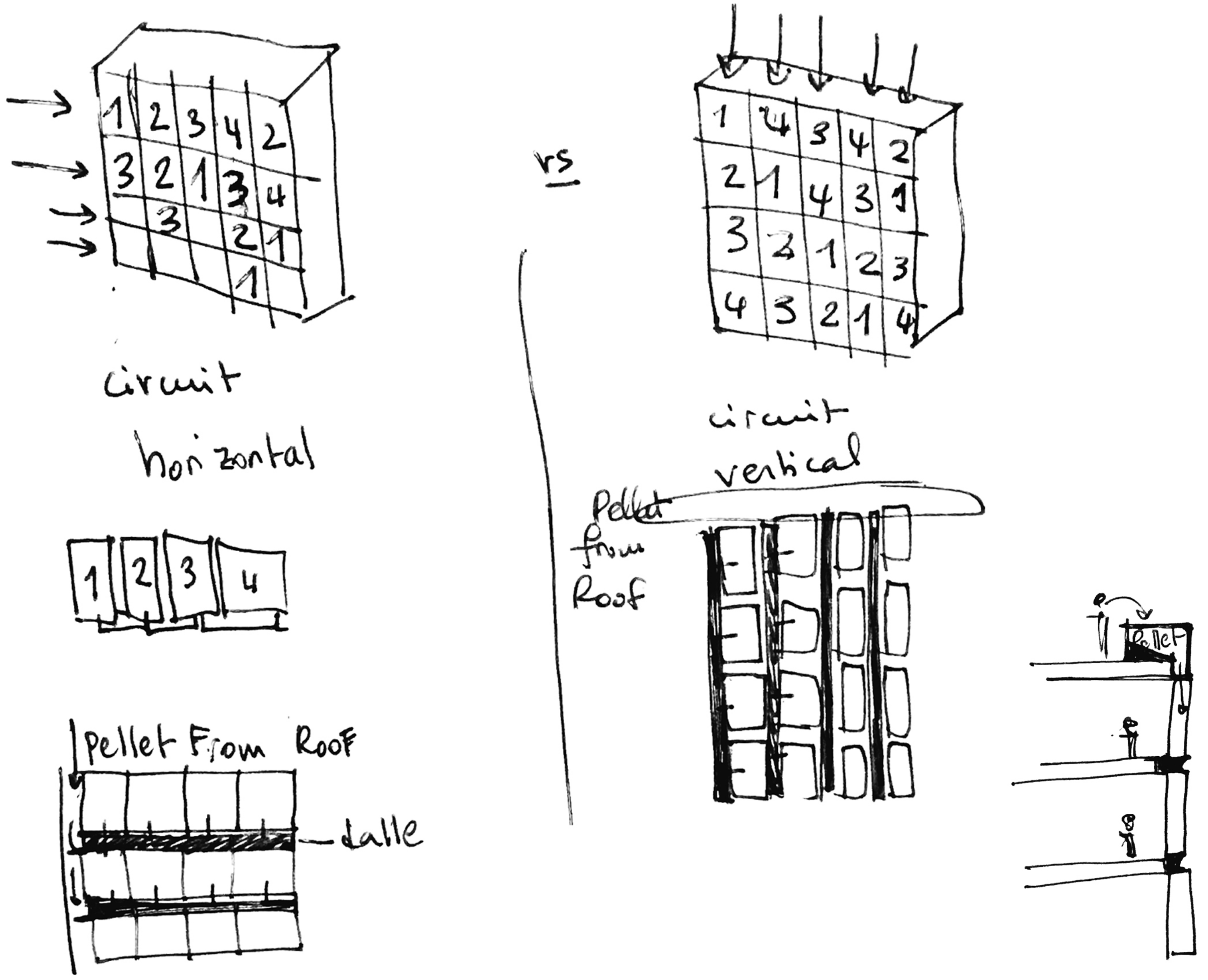
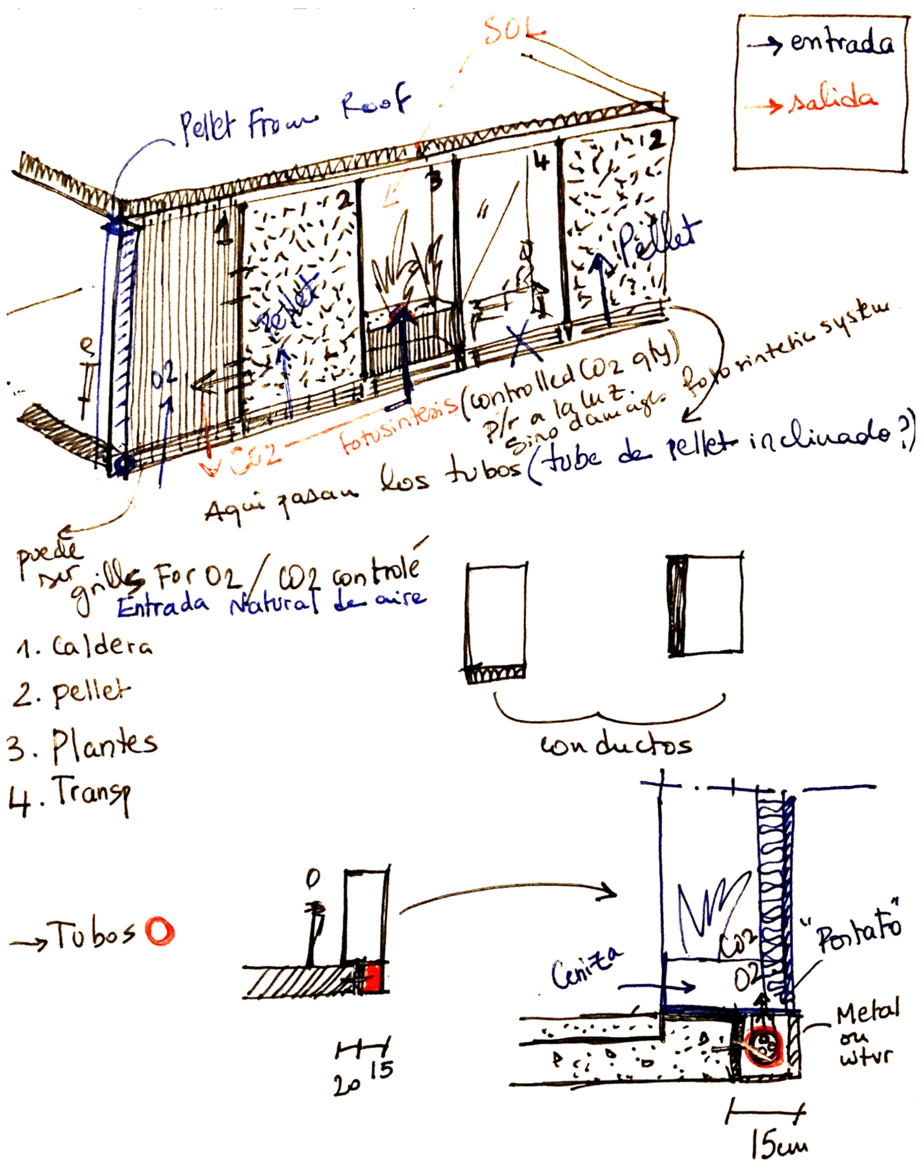
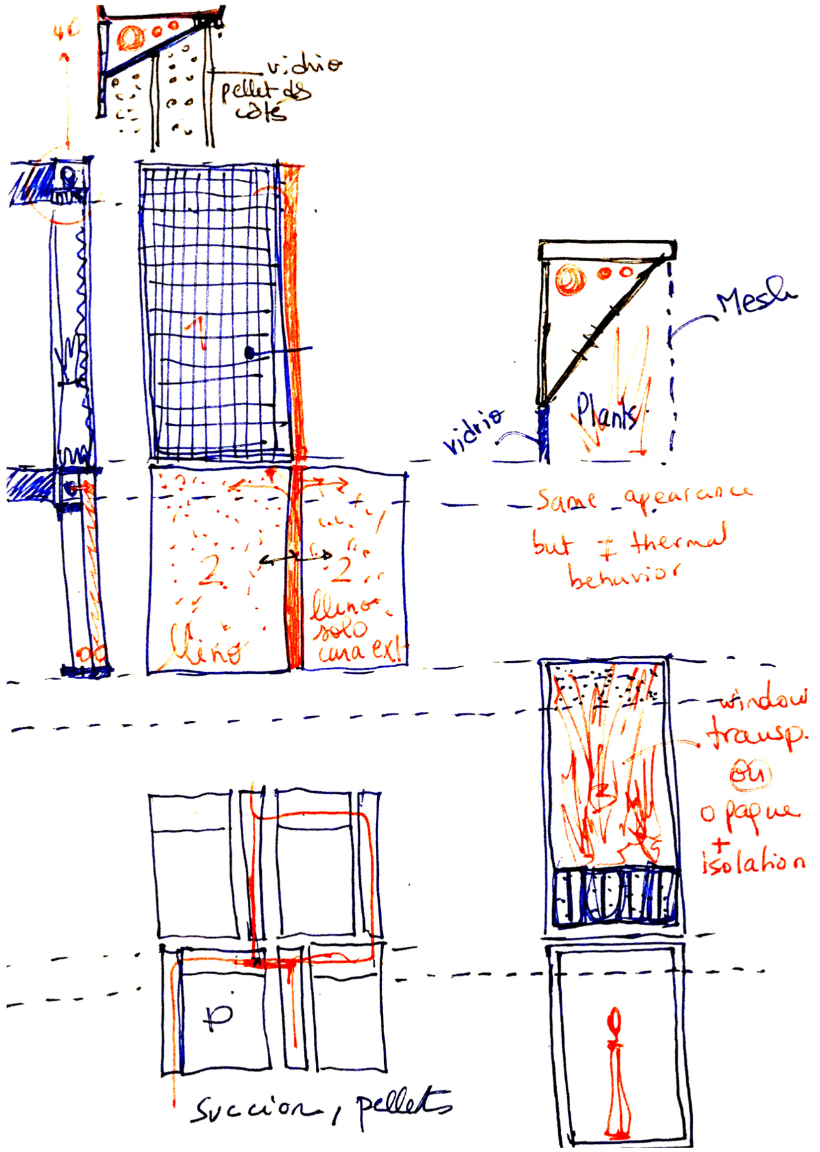
APPENDIX

PROGRESS OF WORK
SKETCHES



PROGRESS OF WORK
SKETCHES





ANALYSIS OF INNOVATION BEHAVIOR

SHADE PLANTS - ADDITIONAL

Barcelona , Zone 10a

Fern

Japanese forest grass

Goutweed

Daylilies

Bleeding heart

Ottawa , Zone 5a

Hosta

Jack-in-the-Pulpit

Astilbe

Hellebore

Lungwort

ANALYSIS OF INNOVATION BEHAVIOR

CALCULATIONS WITH “BALANÇ” EXCEL PROGRAM

E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI
DESFASE (min) 1cm	20	1	1	17	20	11	20	20	18	19	20	23	24	20	3	1	1	34	35	10	19	10	29	35	12	0	3			
VELOCITAT (cm/h)	3.0	100.0	66.7	3.5	3.0	5.5	3.1	3.0	3.3	3.1	3.0	2.6	2.5	3.0	17.6	40.0	100.0	1.7	1.7	5.9	3.1	5.8	2.1	1.7	5.0	###	19.4			
MATERIAL	VIDRE	CAMBRA D'AIRE 1	AIGUA	FORMIGÓ	BLOC DE FORMIGÓ	GRANIT	ARREBOSSAT MORTER	ENGUIXAT	MAÓ MASSÍS	MAÓ CALAT	MAÓ BUIT	TERMOARCILLA > 19cm	TERMOARCILLA ≤ 19 cm	TAPIA	ACER	ALUMINI	CAMBRA D'AIRE 2	FUSTA LLEUGERA	FUSTA PESADA	PE EXPANDIT (IV)	POLIURETÀ LLEUGER	FIBRA DE VIDRE	SURO	GUTEX®	GRAVA	policarbonat celular clar	GUATA	MATERIAL 4	MATERIAL 5	U diurna $(w/m^2*ºC)$
TIPUS				Factor solar el. transparent					0.82			Coef. de fusteria			0.10		Coef. de manteniment				0.90		Rend. global del sistema						0.30	0.78
GRUIX (cm)	1	10															10	10												
AILL. NOCTURN (cm)																							Module 2 : pellet, 1 chamber filled							
CAP. TÈRM./m2																	0	22												
DESFASE (min)	20	6															6	344												
TIPUS				Factor solar el. transparent					0.82			Coef. de fusteria			0.10		Coef. de manteniment				0.80		Rend. global del sistema						0.24	0.49
GRUIX (cm)	1	10															10	20												
AILL. NOCTURN (cm)																							Module 2 : pellet, 2 chambers filled							
CAP. TÈRM./m2																	0	45												
DESFASE (min)	20	6															6	687												
TIPUS				Factor solar el. transparent					0.82			Coef. de fusteria			0.10		Coef. de manteniment				0.90		Rend. global del sistema						0.30	0.36
GRUIX (cm)		13													1.0							10								
AILL. NOCTURN (cm)																							Module 1 : boiler							
CAP. TÈRM./m2															10							1								
DESFASE (min)		8													3							103								
TIPUS				Factor solar el. transparent					1.00			Coef. de fusteria					Coef. de manteniment						Rend. global del sistema						0.00	1.05
GRUIX (cm)	1	10															10				1									
AILL. NOCTURN (cm)																							Module 3 & 4 : plants & balcony							
CAP. TÈRM./m2																	0				0									
DESFASE (min)	20	6															6				19									

CA | DEF MAS | DEF VID | PERF. USOS-H | PERF. USOS-E | SIST ESP | PRAL-H | PRAL-E | INTRO RAD | RADIACIONS | CÀLCULS-H | CÀLCULS-E